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AN APPRAISAL OF AIR POLLUTION IN MINNESOTA

George J. Raschka

Minnesota Department of Health
Minneapolis, Minnesota

January 1961

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AN APPRAISAL OF AIR POLLUTION IN MINNESOTA

A report on a survey by the
Minnesota Department of Health
with cooperation from the U.S. Department of
Health, Education, and Welfare, Public Health Service
October 1959 – July 1960

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MINNESOTA DEPARTMENT OF HEALTH
University Campus
Minneapolis 14, Minnesota
January 1961

FOREWORD

This report owes its preparation to the growing interest and concern about air pollution expressed by the people of Minnesota. It gathers together and interprets as far as possible information presently available and pertinent to the problem in Minnesota. It presents a number of problems for which there are no ready-made solutions. Its function will be well served if it stimulates thinking, planning, and action at the state and local level for the conservation of the vital air resource in Minnesota.

The report is presented in eight technical sections, each of which discusses some single aspect of the air pollution problem. The subject is complicated at best, and the individual sections must be read with the knowledge that their contents are interrelated with the contents of every other section. To assist the reader, an abstract appears at the beginning of each section.

The report is basically technical. It places greater emphasis on presentation of data than on interpretation, but it does point out that air pollution exists in Minnesota in sufficient degree to merit further consideration. It is hoped that the report will serve as a foundation for further study and evaluation.

RN Barr

Robert N. Barr, M.D.
Secretary and executive officer
State Board of Health

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CONCLUSIONS AND RECOMMENDATIONS

Air pollution problems exist in Minnesota in sufficient degree to call for the attention and action of its citizens. They exist in small as well as large communities. The most noticeable effects of air pollution in Minnesota are detriment to public comfort and welfare and damage to property. However, its greatest significance may well be the not-so-apparent possible effects on health and on plant and animal life. All causes and effects should be included within the area of responsibility of the control agency.

In general, Minnesota's weather and terrain are favorable for dispersion of air pollutants, but local weather and terrain are not always favorable. Many communities are located in valleys which restrict movement of air and accentuate those features of weather which are conducive to a build-up of pollutants in the air. Further, some of the weather advantage is off-set by the added load placed on the air due to space heating requirements in Minnesota.

In the light of all available information it is concluded that Minnesota does not now have a severe air pollution problem, when considering the state as a whole. Absence of extensive activity in certain industrial pursuits usually associated with particularly troublesome pollution emissions and widespread use of relatively smokeless fuels for domestic heating are among the factors tending toward lower pollution levels. However, many sources of pollution create localized problems and the concentration of a multitude of pollution sources in large communities, and in smaller communities unfavorably located, tends to create area-wide pollution levels higher than are desirable. Limited air sampling indicates that there are periods now when air pollution reaches undesirable levels. Furthermore, population increases are expected which will be associated with greater industrial activity as well as increased fuel use for heat and power, traffic density, and refuse disposal. All of this will result in greater pollution emissions and, thus, greater pollution of the air resource.

Now is the time to take action to combat air pollution: first, to cope with existing problems and, second, to conserve the vital air resources for the future. Without effective action, the problems of today will be intensified tomorrow and new problems will arise which could be avoided by application of preventive measures.

Local governmental units have not been delegated sufficient authority to deal with air pollution problems, and no readily applicable means are available for resolution of air pollution problems involving more than one political jurisdiction. This is a particularly pressing problem in metropolitan areas.

The state must provide leadership and certain resources to helpmeet those air pollution needs which cannot justifiably be met within the means of most local governments. There is a need for a channel through which experience and knowledge of others can be applied to problems in Minnesota; a need for technical competence to evaluate problems; and a need for air quality monitoring.

On the basis of the findings of this study and present knowledge of the growing problem of air pollution, it is recommended:

. . . that existing legislation be reviewed in the light of the need for greater scope and flexibility at the level of local government;

. . . that the interjurisdictional problems created by air pollution, which does not recognize political boundaries, be resolved;

. . . that special consideration be given to solution of area-wide air pollution problems in metropolitan areas; and,

. . . that provision be made for leadership and technical resources at the state level to assist in the solution of problems at the level of local government.

The goal of air pollution legislation should be to maintain a reasonable degree of purity of our air resources consistent with: a) public health, comfort, and welfare; b) protection of plant and animal life; c) protection of physical property and other resources; d) visibility requirements for safe air and ground transportation; and e) continued economic development and growth.

At all levels of government, air pollution control can be most effectively brought about by reasonable legislation based on technically-substantiated criteria. It should provide adequate flexibility, yet be reasonably specific to meet the needs of the area under consideration.

Present laws in Minnesota, both at the state and local level, are limited in scope and do not adequately meet present and future needs.

INTRODUCTION

ABSTRACT

This appraisal of the air pollution situation in Minnesota arose from a growing concern about air pollution problems in the state. Increasing requests for information and assistance registered with the State Department of Health by local citizens and organizations indicated expanding interest throughout the state. The advice and counsel of the U.S. Public Health Service were obtained concerning methods of conducting a survey which would establish the nature and extent of the air pollution problem in the state and indicate what activity is needed on the part of the state and local governments in meeting the problem.

Data used in preparing this report were obtained by interviews, direct observation, questionnaires, limited air sampling, and review of existing information. The appraisal was made from October 1959 to July 1960.

ORIGIN OF THE SURVEY

In recent years the State Department of Health has been called upon with increasing frequency to give advice, counsel, and technical assistance on community air pollution problems. Sources of pollution have included dust from foundries, a flax mill, sand blasting operations, grain elevators, and plants producing rockwool, electric power, fertilizers, and cement. Complaints have involved foliage damage from chlorine, 2,4-D, sulfur dioxide, and ammonia; paint and metal damage from fertilizers, smoke, hydrogen sulfide, and asphalt road material mixing; odors from oil refineries, a magnesium foundry, paper mills, dry cleaning plants, alfalfa dehydrators, canneries, soybean extractors, and secondary lead smelters. The extent of assistance that could be given was restricted by staff limitations.

Since 1953 the department has participated in National Air Sampling Network activities conducted cooperatively by the U. S. Public Health Service. Some air sampling equipment has been purchased and certain industrial hygiene instrumentation has been adapted to the air pollution field. Some department personnel have been given training in the elements of air pollution problems.

The University of Minnesota recently added a course in air pollution to its curriculum, and a number of research projects on specific air pollution problems are currently in progress. Both Minneapolis and St. Paul have had active smoke abatement programs for a number of years, and a number of other communities have recognized the growing problem, as evidenced by enactment of ordinances or operation of active air monitoring programs. In 1957 the state legislature authorized the State Board of Health to make regulations regarding "atmospheric pollution which may be injurious or detrimental to public health".

The board, cognizant of the present-day implications of air pollution, determined that a state-wide survey of the current and potential air pollution situation in Minnesota was needed. The U. S. Public Health Service, which had conducted or participated in a number of such state-wide surveys, was requested to assist. In September 1959 the State Department of Health decided to conduct a nine-month survey. The U. S. Public Health Service agreed to contribute consultation and material aid.

PROCEDURE

The initial step in the survey was to establish objectives. These were as follows:

a) To assess the nature and extent of air pollution in the state.

b) To inventory and summarize existing state and local legislation related to air pollution.

c) To assess present air pollution activities in the state.

d) To provide a basis upon which state and local agencies may determine the most suitable type of legislation.

e) To provide a basis upon which the state and local agencies may determine the type and extent of activities that should be undertaken.

These objectives were achieved through personal interviews, direct observation, questionnaires, limited air sampling, and review of existing sources of information. The appraisal was made between October 1959 and July 1960.

A questionnaire was sent to the clerks in all 840 municipalities in the state, to health officers in 244 communities having a 1950 population greater than 1,000, and to 60 chambers of commerce (Appendix). Another questionnaire was sent to all county agricultural agents (Appendix). A municipal refuse disposal questionnaire was prepared for use by each of the state's eight district health department offices (Appendix). Questionnaires were returned by 98 per cent of the communities having a population greater than 1,000 (240 out of 244); by 67 per cent of the smaller communities (400 out of 596); and by 88 per cent of the county agricultural agents (75 out of 85).

Representatives of official and non-official agencies were interviewed in 106 communities distributed in all but five counties, with emphasis given to larger cities and to those with previously known major sources of pollution. Data were compiled from various sources on population, industrial growth, fuel use, topography, climatology, and refuse disposal practices.

Air sampling was carried out simultaneously at five stations during three two-week periods to collect air-borne particulate matter. Stations were located at the State Board of Health building on the University of Minnesota campus in Minneapolis, and in the downtown sections of Minneapolis, St. Paul, Duluth, and Fergus Falls. Dustfall jars, collected monthly, were also placed at each station. Gas sampling equipment was operated at the State Board of Health station for collection of sulfur dioxide, ozone, and oxides of nitrogen.

EFFECTS OF AIR POLLUTION

ABSTRACT

There is a growing body of information tending to establish a relationship between air pollution and chronic illness. These long-term effects are indicated by increased morbidity and mortality in urban areas and by increased incidence of certain types of cancer, heart disease, and respiratory illness. Evidence of such relationships in Minnesota were not explored in this survey. The survey reveals that officials in one out of three communities in Minnesota with a population greater than 1,000 have received complaints of the effects of air pollution. The economic effects of air pollution are usually most obvious. They involve discoloration of paint, corrosion of metal, soiling of fabrics and buildings, and damage to plants and animals. Complaints about damage to property and vegetation have been received in one out of eleven communities. Air pollution which interferes with the comfortable enjoyment of life, the use of property, and the conduct of business has been called to the attention of local authorities in one out of six of these communities.

HEALTH EFFECTS

Human life is dependent upon the constant availability of air. It is presumed that people have a right to air which will not be detrimental to their health, comfort, or welfare. However, past experience has shown that air pollution can, especially during periods of unfavorable weather conditions, cause illness and death.

In 1958, Doctors Heimann, Emik, Prindle, and Fisher of the Air Pollution Medical Program of the U. S. Public Health Service summarized principal findings of prior research on air pollution and its effects on man (1). Highlights of their text are quoted.

Locale and Disease

"What are the principal results thus far of our epidemiological studies, preliminary though they may be?

1. There is evidence that the people who were affected by the air pollution episode in Donora in 1948 have more sickness and a higher mortality rate later than their fellow townsmen of similar ages who were not affected.

2. There is evidence that death rates for certain causes increase directly with degrees of urbanization. Specifically, these causes include cancer of the lung, cancer of the stomach and esophagus, and arteriosclerotic heart disease and certain other heart conditions.

3. Short-term increases in air pollution exposures cause changes in the lung function of persons with chronic cardio-respiratory impairments, and this effect may be delayed for 3 or 4 days after exposure. Exposure to 'filtered air' may relieve these symptoms.

Irritants and Breathing

"The second major subject has to do with the effect of air pollution on man's breathing ability. The effects found thus far are essentially those resulting from irritation. The important findings include the following:

1. Irritant gases, such as sulfur dioxide and ozone in amounts similar to those in community air, have an adverse effect upon man's ability to breathe.

2. Continuous or repeated inhalation of ozone scars the lung tissues of animals.

3. Exposure to ozone disturbs the alkaline phosphatase levels in the body, which may indicate that other changes in enzyme and metabolic activity are occurring.

4. Irritant gases cause pulmonary edema and affect enzyme systems and other physiological mechanisms.

5. Inhalation of some irritant gases mixed with certain aerosols that are usually considered physiologically inert increases the adverse effects of the gases.

6. On the other hand, repeated inhalation of small quantities of ozone, and possibly other gases, appears to result in a significant degree of increased resistance to the acute effects of ensuing heavier exposures.

Cancer and Heart Disease

"Our third major subject includes lung cancer, and possibly other cancers, as well as cardiovascular diseases.

"No one can deny that heart disease and cancer are two of the important diseases in this country today. Together, they account for 54 per cent of all deaths. Lung cancer, although accounting for only 1.8 per cent of deaths has been increasing rapidly in recent decades. Statistical studies relate this increase in lung cancer to cigarette smoking. A similar association has been shown with heart disease mortality, which, although less startling in percentages, is even more impressive in total numbers of deaths. What light, if any, have studies on air pollution thrown upon the causes of these diseases?

1. There is evidence that death rates for certain causes of death increase markedly with urbanization. Specifically, these causes include cancer of the lung, trachea, and bronchus, cancer of the stomach and esophagus, arteriosclerotic heart disease, and myocardial degeneration. The increase of lung cancer with population density persists even when the degree of cigarette smoking is held constant.

2. Fragmentary evidence of the distribution of cancer mortality within cities appears to be at least partially related to the distribution of air pollution intensity.

3. Certain air pollutants found in our cities are known to be experimentally carcinogenic for animals. Chemical analysis has disclosed many other potential carcinogens in air; these may also be carried by particulate matter deep into the lung.

Animal Studies

"The fourth subject deals with the effects of different air pollutants. All our previous experience indicates that the chemical and physical nature of substances are important in determining their biological effects. We have not devoted much effort to studying the effects of specific substances, largely because our air sampling information indicates that, as an acute problem, the community levels found are too low, and that as a long-term problem it is not possible to isolate effects due to one substance from those due to others. We have, however, promoted research work on the effects of mixtures of pollutants and especially those that generally simulate the type of pollution in Los Angeles. Some of the significant leads that stem from those studies are the following:

1. Certain nitro-olefins believed on theoretical grounds to be present in Los Angeles air may be among the factors that irritate eyes. Synthetically prepared nitro-olefins have been found to be highly irritating and rapidly fatal to animals in acute exposures. At concentrations believed possibly extant in Los Angeles air at times, they cause eye irritation in man.

2. There is diminished oxygen uptake and decreased growth of micro-organisms exposed to simulated Los Angeles type of air pollution.

3. The fertility of experimental mice and the survival rate of new born mice seem to be reduced by the artificial Los Angeles type of air pollution."

ECONOMIC EFFECTS

Most people in the United States place a high value on cleanliness of their homes and communities. For example, in Milwaukee, in an area proposed for redevelopment, a survey showed only 24 per cent of the people interviewed were satisfied with cleanliness of the area (2). Similarly in Denver, 94 per cent of the people interviewed said cleanliness of the neighborhood was very important in selecting a home. This was the highest percentage of all neighborhood characteristics considered. House values may be $2,000 less in areas affected by air pollution than in areas free of air pollution (2).

Building materials are attacked and disfigured by atmospheric pollutants. Sulfur compounds, for instance, will corrode most building materials, and much less than 0.5 parts of sulfur dioxide per million parts of air by volume will produce some effect. In Springfield, Illinois, surveys showed that the corrosion rate of clean steel surfaces in the city was as much as 30 times that in rural areas (2). Certain white lead base paints readily react with hydrogen sulfide, turning them black.

Soiling of clothing, home furnishings, and building surfaces is evident in dirty atmospheres. This requires more frequent laundering of clothing, cleaning of furnishings, and painting or sandblasting of stained buildings.

Many growing plants are more sensitive than man to the effects of polluted air. In some cases, these plants are used as specific pollution detectors. Sulfur dioxide, fluorides, dusts, and other pollutants have caused severe plant damage, even denuding the landscape for a considerable distance around pollution sources in many cases. Injury to livestock has been reported from aerial contamination of forage material.

TABLE I
Communities Reporting Air Pollution Problems

Population class (1950 census)	No. of communities	Returned questionnaire	Discomfort or inconvenience		Damage to property or vegetation*	
			No.	Per cent of total	No.	Per cent of total
Over 50,000	3	3	3	100	3	100
20,000-50,000	6	6	3	50	1	17
10,000-20,000	18	18	9	50	2	11
5,000-10,000	32	32	20	61	9	27
2,500- 5,000	42	42	14	33	8	19
1,000- 2,500	143	139	39	27	19	13
500- 1,000	151	110	10	7	7	5
250-500	202	134	11	6	6	3
Under 250	243	156	3	1	1	
Total	840	640	112		56	

*In addition to discomfort or inconvenience

EFFECTS OF POLLUTION IN MINNESOTA

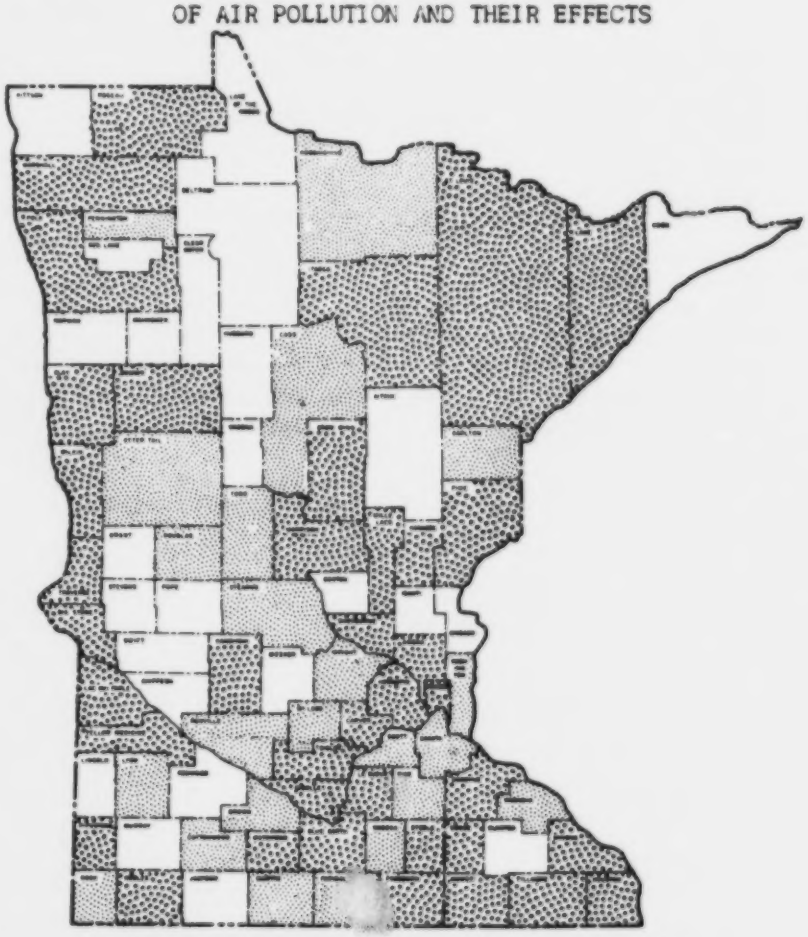
Completed questionnaires indicated recognized pollution sources throughout Minnesota. Thirty-three per cent of the communities over 1,000 population (1950) have air pollution problems as evidenced by public complaints. Although the specific effects of these contaminants were not ascertained, pollution was reported in sufficient concentrations to cause measurable discomfort or inconvenience in 112 of 640 reporting communities. Concentrations sufficient to cause damage to property or vegetation in addition to discomfort to residents were reported in 56 of the 640 communities.

The greatest number of problems occurred in cities of 1,000 to 2,500 population. Outside of cities of the first class (over 100,000) the highest percentage frequency of occurrence was found in the 5,000 to 10,000 population range (Table I).

Questionnaires showed that air pollution sources are scattered throughout the state. Of the state's 87 counties, 26 had no community with a reported air pollution problem. In 61 counties, one or more communities reported measurable discomfort or inconvenience to residents, and in 39 counties, one or more communities reported damage to property or vegetation (Figure 1). The bulk of the problems in the outstate area stem from agriculture-related industries.

Figure 1

DISTRIBUTION OF RECOGNIZED SOURCES OF AIR POLLUTION AND THEIR EFFECTS



AIR CONTAMINANTS WERE REPORTED IN SUFFICIENT CONCENTRATION TO CAUSE:

- No problem — 26 counties
- Measurable discomfort or inconvenience to residents — 22 counties
- Discomfort or inconvenience plus damage to property or vegetation — 39 counties

Typical outstate problems include smoke and milk solids from milk processing plants; ore dust and smoke from iron mining and ore steaming; soot and fly ash from power plants; dust, gases, and odors from food or grain elevators, fertilizer, chemical, and alfalfa dehydrating plants; and gases and odors from meat and poultry processing and canning plants (Table II).

TABLE II
Sources of Pollution in Communities Reporting
Damage to Property or Vegetation

Pollution source	Number of communities reporting problem*
Milk drying, creamery, and cheese plants	15
Iron ore mining	8
Burning of refuse, sawdust, junk autos	6
Sewage	6
Power plants	5
Feed and grain plants	5
Meat and poultry processing	4
Canning plants	4
Alfalfa dehydrating	3
Chemical and fertilizer	2
Miscellaneous or not specified	12

*Some communities have more than one source of pollution. Does not include Minneapolis, St. Paul, and Duluth

SOURCES OF AIR POLLUTION

ABSTRACT

Many activities contribute to the pollution load of the atmosphere. Industry, frequently looked upon as the major source of air pollution, constituted over half of the pollution sources reported in this survey. However, these data do not truly reflect the relative importance of types of pollution sources, since those reported are those which individually have been noticed or caused problems. Proper emphasis is not given to the many smaller pollution sources which collectively may be important but which do not individually attract attention. The food and kindred product industries were recognized more frequently than any other industrial category as sources of air pollution, but there are more of these plants in the state than of the other types. Typical of this group were grain cleaning operations, milk drying, canning, and meat packing. Other typical industrial sources of air pollution were ore steaming operations, asphalt paving material mixing, and kraft paper making.

Combustion of fuels for heat and power releases large quantities of contaminants in the form of liquid and solid aerosols and numerous gases. One-fourth of the fuel consumed in the state is used for space heating. Where natural gas is available it is the dominant fuel for domestic heating. Over half of the fuel oil consumed is used for space heating. Electric utilities are the major users of coal and in 1958 these companies used nearly half of all the coal burned in Minnesota. Use of various fuels does not result in equivalent pollutant emissions, and the emissions vary seasonally because of the severity of the winters, the use of standby fuels, and the intermittent operation of space heating devices in fall and spring.

Emissions from transportation equipment presently are receiving nationwide attention because of possible formation in air of eye-irritating and vegetation-damaging materials. In Minnesota there is one automobile for every 2.8 people, compared with 3.1 nationally, and half of the miles driven are of the low efficiency, stop-and-go, urban driving type. These vehicles consume 3,360,000 gallons of gasoline per day. Nearly one-third of the fuel used in Minnesota is burned in transportation equipment. Many people have experienced the pollution of air by exhaust gases during rush hour traffic. As a first step towards control, every automobile manufacturer has now made available a "blow-by" control device which will reduce hydrocarbon losses by 30 per cent and possibly will improve engine performance.

Waste disposal practices may contribute significantly to the overall pollution emissions of the modern urbanized and industrial community. Smoke and odors from burning dumps were reported by 27 communities. Backyard trash burners are permitted in most communities, with the danger of fire the primary reason why some communities restrict the use of trash burners. The significance of the use of a multitude of such devices to the overall level of pollution in a community is not generally recognized.

Other major pollutants include pollen, smoke from forest and grass fires, and dust from drought areas. Soil conservation practices and modern forest management tend to reduce these pollutants. Those who suffer from hay fever may look forward to a coordinated attack against practices which tend to increase pollen counts.

POLLUTION SOURCES REPORTED IN THE SURVEY

Questionnaires sent to all Minnesota communities, supplemented by data obtained through visits, indicate that over 50 per cent of the communities having a population greater than 1,000 have one or more sources of pollution that have attracted attention. Specific pollution emissions were attributed to all sorts of industrial, utility, waste disposal, and domestic activities (Table III). Half of the sources reported were associated with manufacturing

TABLE III
Sources of Air Pollution Reported in
Municipal Questionnaire and Visits*

	Number of pollution sources**		
	Community population		
Type of pollution source	Greater than 1,000	Less than 1,000	Total
Agriculture	11	3	14
Mining	10	3	13
Manufacturing	148	34	182
Transportation	11	6	17
Public utilities	14	2	16
Service	12	1	13
Sewage disposal plants	20	1	21
Dumps & incinerators	24	3	27
Domestic	10	6	16
Not specified	22	15	37
Total	282	74	356

*Does not include Minneapolis and St. Paul
**Some communities have more than one source

plants. These data do not truly reflect the relative importance of types of pollution sources, since those reported are those which individually have been noticed or caused problems. Proper emphasis is not given to the many smaller pollution sources which collectively may be important but which do not individually attract attention.

INDUSTRIAL ACTIVITY

Minnesota has a highly diversified economy. It ranks fifth in the nation in the value of farm products sold, preceded only by California, Iowa, Texas, and Illinois (3). Its mines have been the primary source of iron ore for the nation's steel industry and, in spite of growing competition from foreign ores, will continue in a dominant role. Its forests, once nearly depleted, now support a substantial forest-products industry. Long a marketing and distribution center for the Upper Midwest, the state is expected to strengthen this position. Its industry has gone beyond its early dependence upon basic resources, and much of the manufacture of durable goods is now geared to the national economy. Its lakes, streams, and climate, which make it one of the vacationlands of the nation, not only are a fringe benefit to the people who live and work in Minnesota, but also add substantial tourist trade to the state's economy.

A comparison of the distribution of employment in Minnesota in 1940 and 1950 with that of the United States shows that Minnesota is significantly above the national average in the agriculture, forestry, and fisheries industry, and considerably below the national average in manufacturing (Table IV).

TABLE IV
Minnesota Employment Distribution (4)
1940 and 1950 Census

	Minnesota employees		% of employees - 1950		
Major industry group	1940	1950	Minn.	U.S.	Minn./U.S.
Agriculture, forestry & fisheries	282,996	260,831	22.8	12.5	1.82
Mining	7,935	15,803	1.4	1.7	0.82
Construction	37,456	63,233	5.5	6.1	0.90
Manufacturing	115,959	186,905	16.4	25.9	0.63
Transportation & public utilities	65,163	95,253	8.3	7.8	1.06
Wholesale & retail trade	172,696	228,208	20.0	18.7	1.07
Finance, insurance & real estate	28,724	37,326	3.3	3.4	0.97
Business & repair service	19,604	32,695	2.9	2.5	1.16
Personal service	69,444	51,322	4.5	6.2	0.73
Entertainment & rec. service	7,601	9,955	0.9	1.0	0.90
Professional service	79,795	107,156	9.4	8.3	1.13
Public administration	32,780	39,689	3.4	4.4	0.77
All others	11,346	15,496	1.4	1.5	0.93
Total	931,499	1,143,872			

In general, this would indicate that air pollution is not as great a problem for Minnesota as for the nation as a whole, since many manufacturing activities are associated with major pollution emissions. However, agricultural employment has declined slowly and presently is about equal to employment in the rapidly growing manufacturing industry (5).

Minnesota's non-agricultural employment has nearly doubled since 1940, from 531,000 to 911,000 in 1959. Wholesale and retail trade and manufacturing are the two largest employment categories, but the largest gain has been in services, with an increase from 94,000 persons in 1950 to 119,000 in 1958.

Manufacturing Industry

Air pollution from manufacturing plants occurs throughout the state. In small communities industrial sources are frequently objectionable because plants are located in commercial-residential areas. In addition, a creamery, a feed mill, a milk drying plant, or an alfalfa dehydrator might be the only industrial pollution source and thus attract more community attention. In larger municipalities attention is divided among many sources, and industries are more likely to be restricted by zoning to areas more or less remote from business and residential sections. Therefore, a pollution source that is considered a problem in a small community might go unnoticed in a large community.

Questionnaires and information obtained through visits indicate that among manufacturing establishments food and kindred products plants are responsible for more reported air pollution problems than any other type (Table V).

TABLE V
Manufacturing Sources of Air Pollution Reported in
Municipal Questionnaire and Visits*

Manufacturing classification	Number of pollution sources**		
	Community population		
	Greater than 1,000	Less than 1,000	Total
Food and kindred products			
Feed and grain	33	7	40
Dairy products	28	9	37
Canning, sugar refining	19		19
Poultry, meat packing, rendering	21	6	27
Lumber, paper and pulp	12	2	14
Chemicals, petro. prod., pri. metals	24	7	31
Other manufacturing	11	3	14
Manufacturing total	148	34	182

*Does not include Minneapolis and St. Paul
**Some communities have more than one source

Manufacturing is playing an increasingly important role in Minnesota's economy. During the 1940-1950 period manufacturing employment increased from 116,000 to 187,000 (4). Value added by manufacturing doubled between 1947 and 1958 (6), increasing from $993,000,000 to $1,995,000,000, while manufacturing employment increased by 25 per cent (Table VI). Minnesota has not had a phenomenal growth in manufacturing, but its rate of growth has been greater than the national average (14% from 1954 to 1958, compared to 10% nationally).

TABLE VI
Manufacturing Statistics for Minnesota (6)

Industry	1958*				1954*			1947*		
	Establish-ments	All employees	Value added by mfg. $1000	Per cent total value added	All employees	Value added by mfg. $1000	Per cent total value added	All employees	Value added by mfg. $1000	Per cent total value added
Food & kindred products	1,212	50,205	469,393	23.5	49,470	398,774	25.0	40,339	250,417	25.2
Machinery, exc. electrical	570	31,710	290,741	14.6	23,492	178,174	11.2	24,068	128,933	13.0
Printing, publishing	808	20,864	166,079	8.3	19,450	138,625	8.7	18,143	105,343	10.6
Pulp, paper & products	79	11,620	144,676	7.2	15,428	173,960	10.9	12,003	103,693	10.4
Chemicals & products	205	6,465	142,868	7.1	5,288	102,484	6.4	4,952	68,205	6.9
Fabricated metals	365	11,924	106,903	5.4	9,707	72,259	4.5	11,174	60,816	6.1
Stone, clay, glass products	330	8,256	93,506	4.7	5,119	31,029	1.9	3,612	15,706	1.6
Transportation equipment	94	5,194	72,137	3.6	6,852	63,452	4.0	3,403	21,056	2.1
Electrical machinery	105	7,641	67,564	3.4	6,680	48,718	3.1	9,105	37,228	3.8
Lumber & wood products	749	7,068	46,701	2.3	8,585	46,818	2.9	6,718	25,707	2.6
Primary metals	80	5,613	46,287	2.3	5,911	34,075	1.9	6,971	29,393	3.0
Apparel & related products	183	7,662	41,126	2.1	8,971	38,962	2.4	9,036	33,684	3.4
All others	547	44,946	306,869	15.4	43,553	267,175	16.8	25,847	112,461	11.3
Total	5,327	219,168	1,994,850	100.0	208,506	1,594,505	100.0	175,371	992,642	100.0

*Data from various years not strictly comparable.

The importance of agriculture in the state is reflected in the food and kindred products classification as compared with other manufacturing groups (Table VI). The production of agricultural machinery accounts for about one-sixth of the employment in the second leading category--machinery (except electrical) (5). Publishing: pulp, paper, and products; chemicals; and fabricated metals are also important to Minnesota's ecomony. The nucleus for a chemical industry based on petrochemical products has been established south of the Minneapolis-St. Paul Metropolitan Area. Most suburban communities in the general vicinity have received complaints of odors emanating from these plants. Statistics for Minnesota's rapidly developing electronics industry (the fourth largest in the nation) have been withheld from census data to avoid divulging individual plant information, but this is becoming one of Minnesota's leading manufacturing industries. It is important to this group of industries that the air be kept as free as possible of dusts and corrosive gases which might interfere with the operation of precision instruments.

Manufacturing in Minnesota is concentrated in the Minneapolis-St. Paul Metropolitan Area. Over 65 per cent of the total value added by manufacturing and 65 per cent of manufacturing employment is in this area. In the outstate area over half of the value added by manufacturing is accounted for by two manufacturing classifications: food and kindred products; and pulp, paper, and products. Outstate employment exceeds that of the metropolitan area in stone, clay, and glass products; lumber and wood products; and primary metals. Of the 5,327 manufacturing establishments in Minnesota in 1958, the outstate area had 2,890 with an average employment of about 26 persons per plant, compared with an average employment of about 59 persons per plant in the metropolitan area. In terms of number of employees and dollar value added, manufacturing growth has been greatest in the metropolitan area, but the percentage growth in this area from 1947 to 1958 (92% for value added and 20% for employment) was less than that for the outstate area (124% and 36%, respectively). As manufacturing industries expand, pollution problems associated with them will become more troublesome unless steps are taken to prevent or control pollution emissions.

Agriculture and Agricultural Industries

Air pollution from farm operations is generally minor. However, dust and odor from pea vineries, harvesting, crop-dusting operations, and livestock feeding lots have caused some problems. Industrial plants processing agricultural products have been a great source of complaint. These processes include milk drying, alfalfa dehydrating, canning, meat packing, poultry processing, grain cleaning, oil extraction, butter and cheese manufacturing, feather processing, and rendering. The chief complaint about these operations concerns malodors. Some cause dust problems. Of the 356 pollution sources recognized in the state's communities (exclusive of Minneapolis-St. Paul), 11 were associated directly with agricultural pursuits and 123 with the food processing industries (Tables III and V).

Farming has been the backbone of the economic development of most of Minnesota. In 1958 farm income totaled $1,510,000,000, of which one-fourth came from marketing of crops and three-fourths from livestock and livestock products (3). The leading crops, in order of importance as sources of farm income, are: corn, soybeans, wheat, flaxseed, oats, and barley (7). In recent

years cattle and calves, dairy products, and hogs have contributed over 50 per cent of all cash farm income.

Agriculture supplies basic materials for one-fourth of Minnesota's manufacturing industry. Corn is raised for hog and livestock feeding, thus contributing to the substantial meat packing industry in South St. Paul and southern Minnesota. In 1957 there were 38 canning and seven freezing plants in the state that processed over nine million cases of sweet corn and five million cases of peas, along with a variety of other products. Minnesota is the third largest wheat flour producing state. The northwestern part of the state is one of the nation's major beet sugar growing and refining areas. Alfalfa dehydrating plants are spotted in the southwestern half of the state. Minnesota ranks third in the nation in production of soybeans and flaxseed, the raw materials for an extensive oil extraction industry (7). Minnesota leads the nation in the production of creamery butter, making over 300,000,000 pounds in 1957. There are about 500 creameries, 95 milk drying plants, 265 pasteurization plants, and 30 cheese factories in the state.

Mineral Industry

The iron mining industry has not been a major source of air pollution, considering the magnitude of the operation. There are certain operations, however, which have led to complaints. Heavy trucking on dirt roads and blowing dust from mine dumps have created dust problems. Ore steaming operations cause fly ash and sootfall problems. It is possible that the increased processing required to up-grade ore for shipping will in some cases create air pollution problems. Sand and gravel processing, especially that involving asphaltic paving material plants, and rock crushing operations are a cause of complaint about dust when near residential areas. Cement plants have caused some complaint of dustfall.

Since 1884, when the first iron ore was shipped from Minnesota, over two billion tons have been mined in the Vermilion, Mesabi, and Cuyuna ranges of northeastern Minnesota. In 1953 over 95 million tons, a record, were shipped from these ranges. A small amount of iron ore is also mined in Fillmore county. Minnesota has been this country's primary source of iron ore, supplying 65 per cent of the domestic ore in 1958. During the last decade competition from foreign ores and the gradual depletion of high-grade direct-shipping ores have created some changes in the mining industry. In 1958, 55 per cent of the ore was beneficiated, compared with 29 per cent for the 1949-53 period. The tremendous capital investment made during this period in beneficiation plants for low-grade ore and in concentrating plants for taconite ore promises a stable mining industry for the foreseeable future (8,9,10). Steel is made in two plants in Duluth.

Certain manganiferous and ferruginous manganese ores are mined on the Cuyuna range. Some is beneficiated and shipped to steel mills. One plant processes these ores to produce high-grade manganese carbonate. These ore deposits may one day be the nation's primary domestic source of manganese.

Although iron mining dominates the mineral picture in Minnesota, other minerals make substantial contributions to the state's economy. Good sand and gravel are in an almost inexhaustible supply in all counties except a few in

the north. Production is at an all time high of nearly 30 million tons per year. Major production is in the areas of greatest population growth and in areas where extensive highway construction is occurring. An increasing market is being found for high silica specialty sands.

Southcentral and southeastern Minnesota have extensive deposits of limestone. Only one cement plant (in Duluth) now operates in the state, although construction of another plant is presently being considered. It would use limestone from Olmsted county. The granite industry, with finishing plants concentrated in the St. Cloud-Cold Spring area, processed 466,000 tons of dimension, monumental, and crushed stone, with a finished value of $4,247,000, in 1958. Basalt from St. Louis county is crushed for concrete aggregate and roadstone. Quartzite from Rock county is used for grinding pebbles and tube mill liners for the mineral industries. Minnesota's peat reserves of several billion tons probably exceed the total reserves of the rest of the nation, but only limited use is made of this resource at this time.

Forest Products Industry

The state is now moving into a forest product era based on management of second-growth timber and on diversified products. Pollutants emitted from the forest products industry include smoke, fly ash, sulfur gases, and odors. Smoke and fly ash arise from the disposal of sawdust and other waste products at sawmills but are of minor importance because operations are usually remote from populated areas. Kraft paper mills are a source of hydrogen sulfide, sulfur dioxide, and mercaptans, all of which have strong and offensive odors. Pole yards are also easily recognized because of their characteristic wood preservative odor. Smoke and fly ash from burning of scrap wood and dust from general operations are a problem at many woodworking plants.

There are some 19,400,000 acres of forest land in Minnesota, of which 80 per cent or 15,600,000 acres are classed as commercial (9). These forest lands cover 36 per cent of the state's area, with a hardwood band separating the pine forests of the northeast from the prairie land of the southwest. The forest industries provide full or part-time employment for nearly 50,000 men (five per cent of non-agricultural workers), with earnings estimated at $134 million annually (11). The annual value of forest products increased from $128 million in 1947 to nearly $200 million in 1958.

In 1954 there were 1,815 sawmills in the state, eight pulp mills (two using the kraft process), 11 veneer mills, 24 lath and shingle mills, 31 pole yards, four other primary wood industries, and over 200 woodworking plants (12,13). The pulp mills, the largest consumers of timber, increased their capacity from 1,135 tons per day in 1945 to 1,685 tons per day in 1955, and to an estimated capacity of 1,900 tons in 1958 (9).

FUEL FOR HEAT AND POWER

Minnesota does not have a domestic source of any major fuel, yet the severity of its winters demands a high fuel use for space heating (Figure 2), higher than other sections of the country. Coal, fuel oil, and natural gas share the state fuel market about equally (Figure 3), although major users

vary markedly in their selection. Industry and electric utility companies use the bulk of the coal. Fuel oil is used primarily for space heating. Natural gas is more evenly distributed among residential, commercial and industrial, and electric utility users (14,15,16).

Natural gas has had the greatest growth rate of the major fuels in recent years. Contemplated extension of pipelines should increase its relative position in the total fuel market. Coal, which has been in decreasing demand, will continue to maintain its competitive position with large users of fuel. Lignite from North Dakota, the major national producer, may find an increasing market in northwestern Minnesota. Fuel oil consumption decreased in 1958 after a long trend of steady annual increase, reflecting perhaps only a temporary adjustment in market. Liquefied petroleum gas probably will find increasing use in a selective market but will not be great competition for the major fuels. The demand for kerosene is not expected to increase and hydroelectric power will continue to play a minor role in the energy field. Atomic energy is scheduled to make its first contribution as a source of energy in Minnesota in the spring of 1961, when a small 22,000 kilowatt power reactor is completed (25).

The type and quantity of pollutants emitted from fuel burning installations are determined principally by the type of fuel used. However, the nature and condition of firing equipment, firing practices, and effectiveness of air cleaning equipment modify emissions considerably. Data on emissions from fuel combustion are

Figure 2

FUEL CONSUMPTION BY MAJOR USE
1958 (10,14,15,16,32)

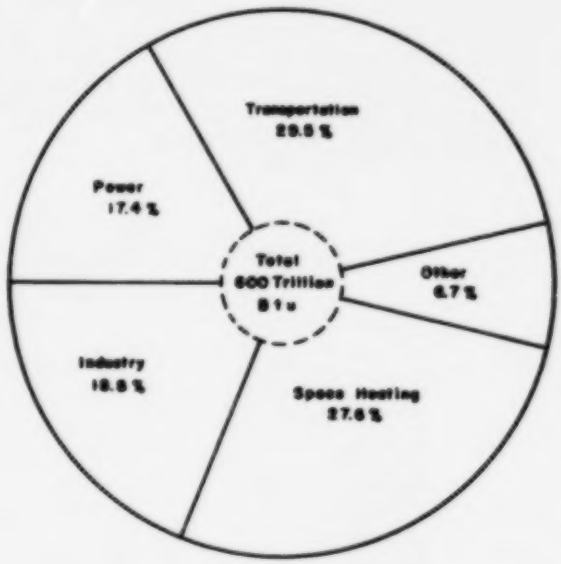
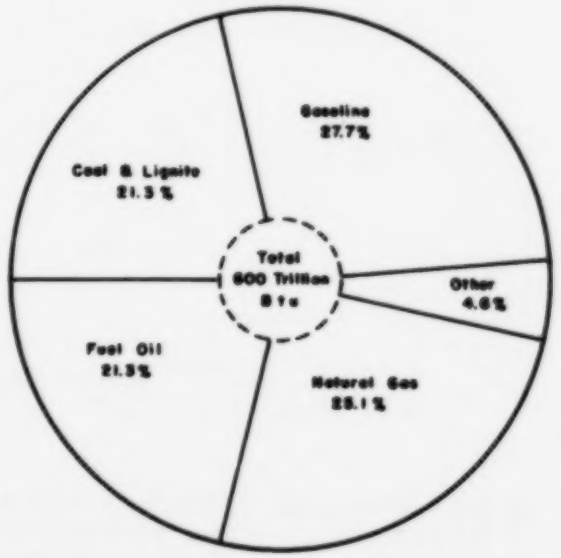


Figure 3

FUEL CONSUMPTION BY TYPE OF FUEL
1958 (10,14,15,16,32)



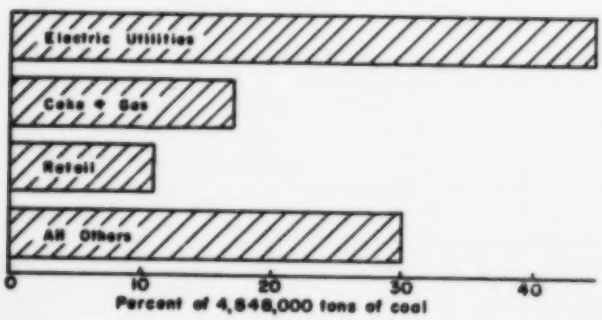
presented (Table VII) to indicate general amount and composition of pollution from each fuel and should not be applied to a specific situation without due consideration of many variables. Emissions from combustion of fuels present problems not completely solved solely by visible smoke abatement programs. The pollutants that cannot be seen have a great potential hazard for health and economic growth. The efficiency of air cleaning devices varies with the size of dust particles. Thus, the average size of particles in the air tends to be smaller and of such size that they may serve as nuclei for penetration into the lungs of a number of contaminants that might seriously affect health. Increasing fuel use may increase the concentration of certain gases which have serious health implications.

TABLE VII
Pollutant Emission Rates from Public Consumption of Fuel (17)
(Highly Variable)

Component	Measured as	Pounds of pollutants per 12×10^6 Btu* released		
		Coal	Oil	Gas
Solids	----	100	0.6	0.1
Sulfur oxides	SO_2	20	12.0	0.3
Nitrogen oxides	NO_2	4	4.2	5.8
Organics	----	10	3.0	1.2
Acids	Acetic	15	9.0	1.1
Aldehydes	HCHO	1	0.6	0.7

*12×10^6 Btu approximates 1,000 pounds of coal, 84 gallons of fuel oil, or 12,000 cubic feet of natural gas

Figure 4
USE OF COAL - 1958 (10,14)

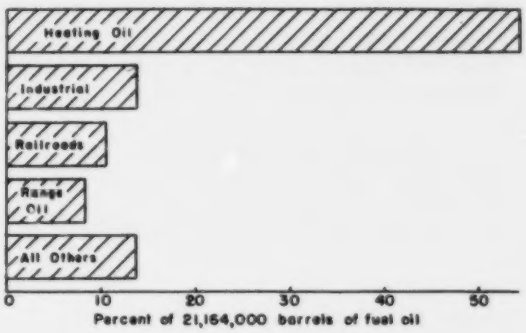


The amount of coal and lignite consumed in Minnesota in 1958 for all purposes was 4,848,000 tons (10,14). Figure 4 shows the distribution by user. Except for consumption by electric utilities, coal has been in decreasing demand for most uses in recent years. Since 1950 the tonnage delivered at lake and river docks (18) has decreased 17 per cent. A major loss represented by conversion by railroads to the use of diesel engines (914,000 tons of coal in 1950 to 41,000 tons in 1958) has been offset by increasing use of coal by electric utilities. In 1959 a steam-electric plant designed to burn pulverized lignite went into operation in Fergus Falls (19). Proximity of the northwestern corner of Minnesota to North Dakota lignite fields suggests an increasing use of this fuel in that area.

A total of 21,164,000 barrels of fuel oil were used in Minnesota in 1958 (10,15), an increase from 14,880,000 barrels in 1950 and 6,939,000 barrels in 1940. Space heating consumed 54 per cent of the fuel oil used in 1958 (Figure 5). Sales for space heating increased from 5,484,000 barrels in 1940 to 9,873,000 barrels in 1950 to 11,372,000 barrels in 1958. The use of fuel oil has also increased in all other categories. Railroad use has increased from 67,000 barrels in 1940 to 993,000 in 1950 to 2,194,000 in 1958. With conversion from steam to diesel power practically complete, future use will reflect volume of rail traffic. Also, 1,667,000 barrels of kerosene were used in Minnesota in 1958. Of this 1,516,000 barrels were used for range oil, 19,000 barrels for tractor fuel, and 132,000 barrels for other purposes.

Figure 5

USE OF FUEL OIL - 1958 (10,15)



Pipeline delivery of natural gas to Minnesota in 1958 amounted to 149 billion cubic feet (10,16), an increase from 104 billion cubic feet in 1953 and 53 billion cubic feet in 1948. Over one-third of the natural gas is consumed by residential users (Figure 6). Sixty-six Minnesota communities were served with natural gas by the end of 1950 and 100 by the end of 1958 (Figure 7). During 1959, 44 more communities were added to the system through pipeline extensions to the north and northwest of Minneapolis and St. Paul. At

Figure 6

USE OF NATURAL GAS - 1958 (10,16)

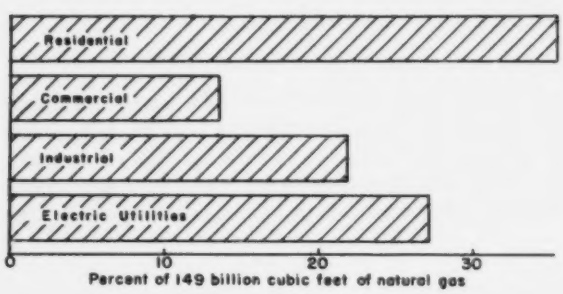
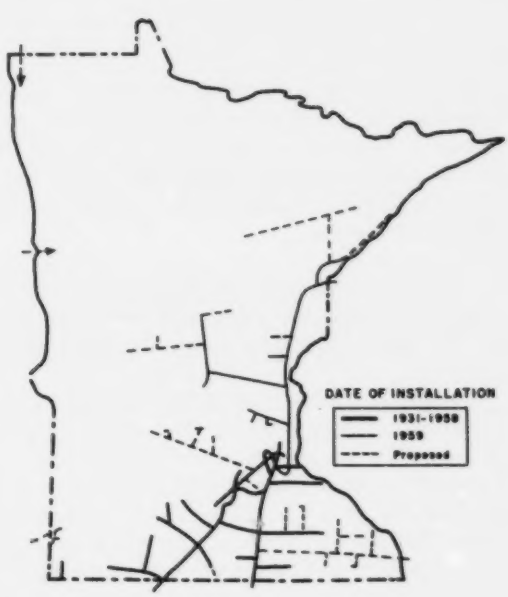


Figure 7

NATURAL GAS PIPELINE TRANSMISSION SYSTEM (20)



the end of 1959 over 50 per cent of the state's population lived in communities served by natural gas (20).

Service by this system to another 100 communities is likely within the next several years. A new pipeline is expected to enter the northwestern corner of the state in 1960 from Emerson, Manitoba, crossing the state in a southeasterly direction and terminating in Marshfield, Wisconsin (21). As gas becomes available extensive utilization tends to follow (22).

In addition to natural gas, 154,000,000 gallons of liquefied petroleum gas were used in 1958, an increase from 68,000,000 gallons in 1950. Still, in 1958 manufactured gas and liquefied petroleum gas added only one per cent to the total gas volume sold through distribution systems (16).

Fuel Used By Electric Utility Plants

All of the large electric utility plants in the state are the steam-electric type. There are many internal combustion and hydroelectric type plants, but these have very small generating capacity (Table VIII). Four large private electric utility companies generate and distribute about 80 per cent of the power supply in Minnesota (9).

TABLE VIII
Electric Utility Plants in Minnesota - 1957 (23)

Type	Number	Total capacity-kilowatts
Steam-electric	61	1,864,802
Internal combustion	67	186,515
Hydroelectric	28	173,896

In 1958 electric utility companies used nearly half of all the coal and one-fourth of all the natural gas burned in Minnesota. Of the 1,734,000 tons of coal burned by 29 of the larger steam-electric utility plants, 852,000 tons or 50 per cent was used by three large plants in the Minneapolis-St. Paul area (24). These three also used 82 per cent of the natural gas consumed by utility plants.

Fuel used by the 29 large steam-electric plants in Minnesota was 52 per cent coal and 48 per cent natural gas; fuel oil is not competitive. The trend in recent years has been towards use of natural gas (Table IX).

About three per cent of the electricity produced in the state is hydroelectric. Power from St. Anthony Falls was instrumental in making Minneapolis one of the major flour producing centers in the country. The prospect for further development of hydroelectric power in Minnesota is limited. Since Minnesota is in a relatively high fuel-cost area, atomic energy may find a competitive position in this state sooner than it will in other sections of the country better endowed with fuels, but for some years to come coal will play a leading role as a source of energy for the production of electricity.

TABLE IX
Steam-Electric Plant Fuel Consumption
and Unit Costs in West North Central United States* (24)

	Fuel consumption-1000 tons			Cost per million Btu-cents		
Year	Coal	Gas** (Coal equiv.)	Oil** (Coal equiv.)	Coal	Gas	Oil
1958	7089	7520	39	28.1	22.0	51.3
1953	6560	5840	199	28.8	21.1	35.8
Change	+ 529	+ 1680	- 160			

*West North Central U. S. includes North Dakota, South Dakota, Minnesota, Iowa, Missouri, Kansas, and Nebraska

**One ton of coal is equivalent to 168 gallons of fuel oil and 24,000 cubic feet of natural gas

The bulk of the coal consumed in Minnesota, at least that used by utility companies, comes from Illinois. Access to the Mississippi River for barge shipping provides transportation at costs lower than other means. Duluth and areas around Lake Superior ship in coal through the lakes from West Virginia, Pennsylvania, Kentucky, and Ohio. An analysis of coal used by one of the major power plants shows it to be a high volatile coal with a slightly low heat content (11,135 Btu per pound) (26). Typical analysis of coal burned by other consumers is shown in Table X (27).

TABLE X
Coal Analysis (as received)

	Per cent dry basis	
Component	A major power company (26)	Other typical consumers (27)
Volatile matter	40.1	33.6
Fixed carbon	54.3	56.8
Ash	5.6	9.6
Moisture	6.4	11.6
Sulfur	2.7	3.1

The major power companies employ dust collectors to reduce smoke and fly-ash emissions and high stacks to provide dilution of the effluent. Still, in view of the large quantity of fuel consumed, they are a major source of gaseous pollution.

Frequently, the small public or municipal utility plant does not have pollution control equipment. Four municipal power and heating plants were reported to cause pollution problems. In addition, smoke from public buildings was listed as a problem in four cases.

Fuel Used By Industry

The estimated 1958 fuel consumption by industry indicates that coal is the leading fuel, however, the demand appears to be lessening (Table XI).

TABLE XI
1958 Fuel Consumption by Industry (10,14,15,16)

Fuel	Quantity	Potential energy Btu x 10^{12}
Coal	2,295,000 tons	55.4
Natural gas	33,194,000 MCF	33.2
Fuel oil	2,890,000 bbls.	17.7
Liquefied petroleum gas	21,549,000 gal.	2.0

The use of natural gas by industry has risen rapidly in recent years following pipeline extensions by Northern Natural Gas Company, and is expected to continue in a competitive role in the future. In communities using natural gas, it is the practice for certain large users of gas to use a standby fuel such as fuel oil or coal when the average outside temperature drops below a predetermined level. At the time of this change, efficiency of combustion is likely to be poor, resulting in substantial smoke emission. Many air pollution problems are due to the inefficient use of fuel. Both mechanical deficiencies and improper operations result in increased air contaminants in the stack gases.

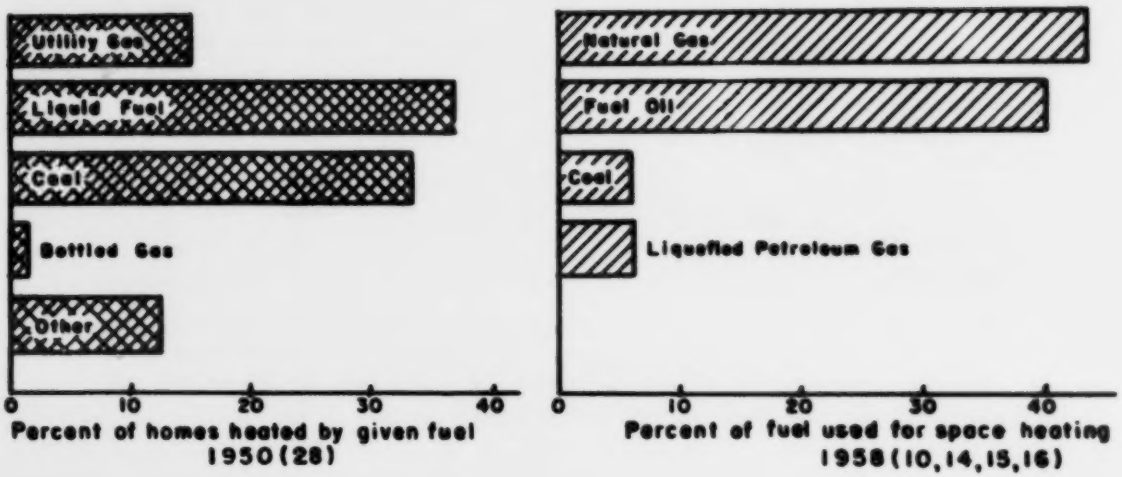
Fuel Used For Residential Heating

In 1950, the most used fuel for home heating was fuel oil, followed by coal, and then utility gas (28). Comparable data for 1958 are not available, but some approximation can be made from current information on fuel distribution as summarized in the preceding pages. These data suggest that over one-fourth of the fuel used in Minnesota in 1958 was for space heating. Natural gas had taken first place, followed by fuel oil, with coal and liquefied petroleum gas sharing third place (Figure 8). The trend for home heating has been away from the solid fuels.

In 1950, 32 per cent of all residences in the state and 36 per cent in urban areas were heated by coal (28). A 1958 survey showed that only three per cent of Hennepin county residents heated their homes with coal; 16 per cent with fuel oil; and almost 81 per cent with natural gas (29). The use of gas has expanded rapidly. The rate of future growth will be determined by extension of pipeline systems. Fuel oil has maintained its proportion of the domestic heating field by gains at the expense of solid fuels in areas not served by natural gas. Liquefied petroleum gas has its greatest use in areas where there is promise of extension of utility gas systems. Data on use of electricity for space heating are not available, but such use is increasing and will require increased fuel use by power generating plants. The number of communities in the state where steam for residential and commercial heating is provided from a central steam plant is decreasing.

Figure 8

USE OF FUEL FOR SPACE HEATING - 1950 and 1958



Consumption of fuel for space heating is not evenly distributed over the year but is proportional to the daily and seasonal heat demand. For the amount of fuel used, the space heating contribution to air pollution is disproportionately higher in the early and late parts of the heating season when furnaces are run on a more intermittent, and therefore less efficient, basis than during the colder part of the heating season.

FUEL FOR TRANSPORTATION

Motor Vehicles

The role of automobile exhaust in air pollution is of increasing concern in large metropolitan areas throughout the country, and it may well be of equal concern in some smaller communities where terrain and weather limit dispersion of air pollutants. Motor vehicles emit significant quantities of carbon monoxide, hydrocarbons, and nitrogen oxides and relatively smaller amounts of aerosols, sulfur dioxide, aldehydes, ketones, and other organic gases (Table XII). Other pollutants result from the use of gasoline additives in addition to tetraethyl lead such as boron, phosphorus compounds, and detergents. Motor oils and their additives are another source of pollution. Also, the amount of gasoline lost directly to the atmosphere by evaporation or by blow-by past the cylinder walls is considerable.

In 1958 there were 1,583,062 motor vehicles registered in the state (31). This includes approximately 1,200,000 automobiles, 5,000 buses, 10,000 motorcycles, and 250,000 trucks. There was one automobile for every 2.8 people (the national average is one for every 3.1 people) (3). These vehicles consumed 1,227 million gallons of gasoline or 3,360,000 gallons per day (32).

TABLE XII
Emission of Air Contaminants from
Gasoline Powered Vehicles* (64)

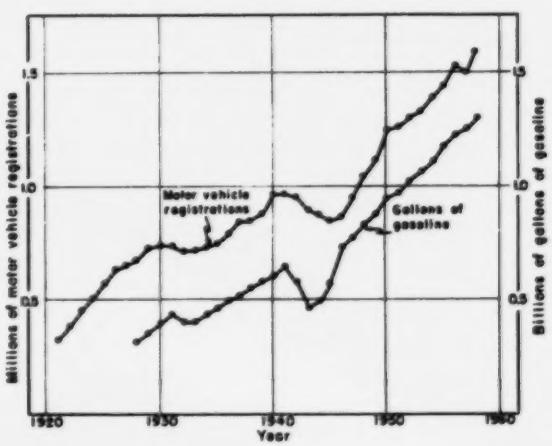
Pollutant	Pounds lost per 1,000 gallons of gasoline burned
Hydrocarbons	300
Aldehydes and ketones	4
Other organic gases	5
Carbon monoxide	1,440
Oxides of nitrogen	146
Sulfur dioxide	17
Aerosols	11

*Does not include "blow-by" losses, which would add about 30 per cent to the hydrocarbon losses, or evaporation losses from fuel tanks, carburetors, and handling of gasoline, which would add another 20 per cent to the hydrocarbon losses (78,79)

Motor vehicle registration and gasoline consumption show the same general growth trends,with dips during the depression years of the early 1930's and during the war years of the 1940's. Since World War II the growth rate for both has been consistently high (Figure 9). The use of gasoline per vehicle has increased from 590 gallons in 1930 to 620 in 1940, to 740 in 1950, to 840 in 1958. Some of this increase reflects increased horsepower and some, the lower efficiency of stop-and-go urban driving. Traffic flow data (and therefore pollution emission rates) show considerable variation according to the season of the year, the day of the week, and the hour of the day. The Minnesota Department of Highways reports that 12.66 billion vehicle miles were driven in 1958 (33). Of this, 47 per cent was on urban streets, 38 per cent on rural trunk highways,and 15 per cent on rural roads. Thus, vehicle exhausts make a substantial contribution to the pollution load of urban areas. Their contribution has been increasing and is expected to continue to increase.

Figure 9

MOTOR VEHICLE REGISTRATION AND
GASOLINE CONSUMPTION 1921-1958(31,32)



Railroads and Vessels

Sixteen major railroads serve Minnesota. Main line trackage in the state totaled 8,233 miles in 1957 (3). In 1958 these railroads used over two million barrels of diesel oil and only 41,000 tons of coal. At present the conversion from steam to diesel-electric

locomotives is virtually complete. Steam locomotives were major contributors of polluting gases, smoke, and particulate matter. Diesel-powered locomotives emit gaseous combustion products, including hydrocarbons, nitrogen oxides, sulfur dioxide, aldehydes, and organic acids. Improperly operated or maintained locomotives also emit excessive smoke. Consideration must be given this source of air pollution in urban areas where rail movement is concentrated.

In 1957 the Duluth-Superior port handled 60,692,000 tons of cargo and Two Harbors handled 19,174,000 tons (3). The bulk of shipments was iron ore, but coal receipts and grain shipments were also large. The opening of the St. Lawrence Seaway and the Great Lakes to ocean-going vessels gives rise to considerable optimism regarding the economic future of the "Head of the Lakes", but also gives rise to a greater likelihood of more air pollution arising from ships, both from propulsion power units and from power units used in loading and unloading.

The 1959 tonnages for the ports of Minneapolis and St. Paul on the Mississippi River were 896,000 and 3,389,000 tons, respectively. After the upper harbor is completed in Minneapolis in 1963, this port will be able to handle an additional two million tons of commodities annually. In addition, 14 miles of the Minnesota river are open to navigation, and in 1958 one and one-fourth million tons of commodities were handled on that section of the river (34,35). The handling of bulk commodities such as grain, coal, and iron ore at river and lake terminals may involve the introduction of considerable amounts of dust to the environment. Most towboats are diesel-powered and do not contribute significantly to the air pollution load since they consume only a small amount of fuel. A few smoke problems of local concern may arise from river boats.

WASTE DISPOSAL OPERATIONS

Questionnaires received from local authorities (Table III) indicate that refuse dumps have been a source of complaint in 24 communities, incinerators in three communities, and odors from sewage treatment plants in 21. In addition, a number of complaints relate to waste disposal operations at food processing plants. There have been some complaints about odors from malfunctioning sewage disposal systems serving individual residences.

Present refuse disposal practices in 240 Minnesota communities having a 1950 census population greater than 1,000 are summarized in Table XIII.

TABLE XIII
Refuse Disposal Practices in 240 Minnesota Communities

Disposal practice	Number of communities
Provision for garbage collection	203
Provision for rubbish collection	173
Sanitary landfill	31
Open dump	179
Control at dump	93
Burning at dump	183
Incinerators	6
Hog feeding	23
Backyard burning prohibited	29

Fifteen per cent of these communities do not have formal arrangement for private or public collection of garbage, and 28 per cent do not provide for rubbish collection. Dumps are used for disposal in 210 communities and, of these, 31 might be considered sanitary landfills. Only 45 per cent of the dumps are provided with measures for control such as an attendant, fencing, selective burning, selective dumping, and limitations on scavenging. Burning is the general practice at 87 per cent of the dumps. A number of communities, especially in the Minneapolis-St. Paul Metropolitan Area, have not made provision for ultimate disposal of refuse but depend on private collectors hauling to dumps in adjacent areas. Only six communities were using municipal incinerators at the time of this survey. Hog feeding is practiced in 23 communities for disposal of selected garbage.

Lack of control over residential refuse disposal was indicated by the finding that only 29 communities prohibited backyard burning, and this was chiefly a fire control measure in the northern forest areas. A number of additional communities prohibit burning of garbage. Other communities restrict rubbish burning to the early evening hours, an undesirable practice from an air pollution standpoint, since dispersion conditions are often poor during early evening. Table XIV shows the air pollution emissions associated with backyard incineration.

TABLE XIV
Emission of Air Contaminants from Incinerators (65)

Pollutant	Measured as	Pounds emitted per 100 pounds of waste burned	
		Domestic	Municipal
Organics	----	13.7	0.06
Aldehydes	HCHO	0.2	0.07
Acids	Acetic	0.04	0.03
Sulfur oxides	SO_2	0.1	0.1
Nitrogen oxides	NO_2	0.025	0.1
Ammonia	NH_3	0.1	0.02
Solids	----	0.12	1.2

As population increases, more wastes will be created which must be disposed of. Unless methods and equipment for disposal which will minimize pollution emission are used, pollution due to waste disposal will increase markedly in the future. Changes in existing practices which will reduce pollution problems can also be made.

OTHER SOURCES OF AIR POLLUTION

Man and nature, acting together, contribute further to pollution of the air. Hay fever sufferers are well aware of the significance of pollen in the air. Smoke palls from forest, grass, and peat bog fires have been serious contributors to air pollution. Dust storms are common in the state. These alone or in combination can intensify local air pollution problems.

In Minnesota a great many plants depend upon the wind for pollination. Certain individuals have an allergic response to these pollen. The majority of people having such an allergy are sensitive to ragweed pollen. In the Minneapolis-St. Paul area the 10 most abundant and clinically most offending kinds of pollen in approximate descending order of importance are: ragweed, wormwood-sago, grass, Russian thistle, pigweed, dock, oak, elm, birch, and nettle (63). In general, pollen counts are lowest in the northeastern section of the state. While air-borne pollen is nature's way of perpetuating certain plant life, the activities of man influence the extent of the problem through cultivation and land use practices. Highway maintenance crews, weed inspectors, agricultural agents, and other groups and individuals contribute to the control of certain sources of pollen. Since pollen is widely dispersed by the winds and since local control programs usually have little noticeable effect, an intensive coordinated attack on the most serious offenders would be necessary to provide hay fever sufferers with a degree of relief.

In 1957, over 80,000 fires burned nearly three and one-half million acres of forest land in the United States. Forest fires have been frequent in Minnesota. Over a million dollars a year are spent in this state to prevent and combat such fires. At times the smoke pall from these fires has covered large sections of the state. Also, large acreages of grass land are burned each year, some of it intentionally. In some instances such fires have penetrated into peat bogs, where they have smoldered for years. All of this contributes substantially to the general level of air pollution.

During the 1930's dust storms originating in drought stricken areas of the Midwest and Southwest swept into the state. To a lesser extent similar clouds of dust occurred during the early 1950's. In recent years high winds during extended periods of dry weather have brought days when the general level of dustiness was many times the average level when measured by high-volume air filter technics. In more localized areas open fields without vegetative cover and land denuded preparatory to housing or highway developments have been sources of blowing dust and sand which infiltrates houses.

A variety of commercial and service establishments,including dry cleaning plants, restaurants, garages, and filling stations, have also been the subject of complaint. Such establishments are common to most communities.

AIR SAMPLING ACTIVITIES

ABSTRACT

There are only limited air quality data available in the state by which to appraise the extent of air pollution. Concentration of suspended particulate matter, collected with high-volume air samplers, is generally somewhat less than the average found in cities of comparable size for the nation as a whole. This type of pollution reaches its peak during the winter heating season, and in urban areas the level of pollution is many times that which exists in a non-urban area represented by the Grand Marais station. Soiling data, collected by use of low-volume filter tape samplers, indicate a similar seasonal variation in level of pollution and also a variation with day of the week and hour of the day. One rating system indicates that ten per cent of the time the soiling index falls in a heavy classification with maximum values considered extremely heavy. Dustfall has decreased over a 13-year span in St. Paul, reflecting a change in the pattern of fuel use.

Gaseous pollutants are invisible and not often recognized by the human senses, but their presence in the air may be equally or more important than particulate pollutants. Sulfur dioxide levels were found to be two and one-half times as high in December and February as in November, with the maximum readings approaching the level considered "adverse" in Los Angeles. Oxides of nitrogen levels were twice as high in winter as in the fall sampling period. The seasonal difference is less for oxides of nitrogen because vehicular exhaust makes a sizable contribution to its concentration. Ozone concentrations were four times as high in the fall as in the winter and would be expected to be even higher in the summer, when more intense sunlight would play a more important role in its formation. Individual samples were found to exceed the level where vegetation damage and eye irritation might be expected.

The results obtained indicate that at times air pollution concentrations approach the level where unwanted effects can occur. There is a need for more sampling, both generalized and for study of specific problems, to delineate the extent and nature of the air pollution problem in Minnesota.

NATIONAL AIR SAMPLING NETWORK

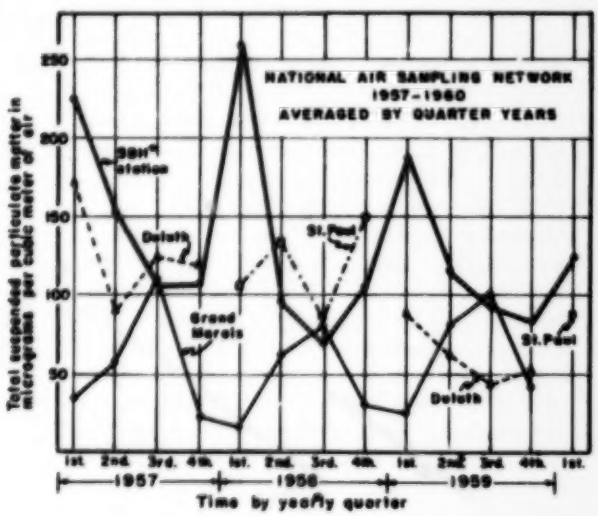
Since October 1953, the Minnesota Department of Health has participated in the National Air Sampling Network, in cooperation with the U. S. Public Health Service. An air sampling station is operating on the roof of the State Board of Health building on the university campus, Minneapolis. In 1960, 135 urban and 37 non-urban stations throughout the nation were cooperating in this network. Stations are operated in Duluth and St. Paul in alternate years, and one non-urban station (in Grand Marais) completed three years of cooperation in December 1959. Early in the program, samples were also collected at suburban stations in Rosemount, Tonka Bay, and Edina. In network operations,

samples of air-borne particulate matter are collected during a randomly scheduled 24-hour period every two weeks with a high-volume air sampler.* The filter on which the dust is collected during each sampling period is sent to the U. S. Public Health Service for analysis. A series of papers interpreting the data from this program has been published (66-74). In general, Minnesota stations show results slightly below average for communities of comparable size.

Figure 10 shows National Air Sampling Network data for Minnesota collected since 1957. Generally, the values presented are the average of six or more determinations in the designated quarter-year. It is interesting to note that the peak concentrations occurred during the January-March quarter at the State Board of Health station. At the non-urban Grand Marais station the general level of particulate contamination was considerably lower, and the peak concentrations occurred during the July-September quarter. Since the activities of man are limited at the Grand Marais station, the values found are a measure of natural seasonal variation and are influenced by drought, snow cover, and growing season. At urban stations, the space heating requirement is the most apparent major additive activity that can account for the higher winter season values.

Figure 10

SUSPENDED PARTICULATE CONCENTRATIONS



*SBH is State Board of Health

STATE HEALTH DEPARTMENT

Since April 1958, the State Department of Health has operated a low-volume filter tape sampler almost continuously at the State Board of Health station.

. . . . . .

*Three methods of collecting and measuring air-borne particulate matter (dust) are discussed in this section: namely fallout jars, high-volume air samplers, and low-volume filter tape samplers. Fallout jars are generally left exposed for a period of 30 days, after which the weight of settled dust is calculated to give results in terms of tons per square mile per month. High-volume air samplers draw about 45 cubic feet of air per minute through a filter. Material collected is weighed (and analyzed if desired) to give results in terms of micrograms per cubic meter of air. The low-volume filter tape samplers draw about 25 cubic feet of air through filter paper during a two-hour period; the dust density is measured in terms of reduction in light transmission through the filter and is expressed on a scale of COHS per 1,000 linear feet of air.

Air is drawn through a small spot on the tape filter for a period of two hours. Then the tape shifts and the sampling is repeated. Difference in light transmission between clean filter paper and the sample spots is measured. Results are expressed in COH units, which are an index of the soiling ability of pollutants in the air.

Examination of data from more than 8,000 samples collected by the low-volume filter tape sampler at the State Board of Health station shows that average monthly soiling unit values vary in the same way as heating degree days with remarkable consistency (Figure 11). This indicates that space heating is a major source of pollutants which cause soiling. The soiling index also varies with the day of the week and with the time of the day (Figure 12). The lower weekend values indicate that industrial and commercial activities make a substantial contribution to the soiling effects. During the 24-hour day two peaks are noted, one before midnight and the other near the time of sunrise. The curve at the bottom of the figure shows that wind velocity was less than eight miles per hour 40 per cent of the time during the nighttime hours. Air pollution as measured by soiling effect decreases markedly as the wind velocity increases at sunrise. The smaller early morning valley in the hourly soiling unit curve probably reflects a decrease in human activity.

Figure 11

AVERAGE MONTHLY SOILING UNIT VALUES
(State Board of Health Station)

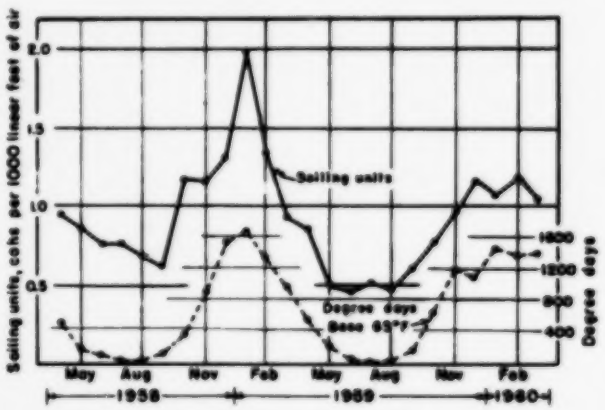
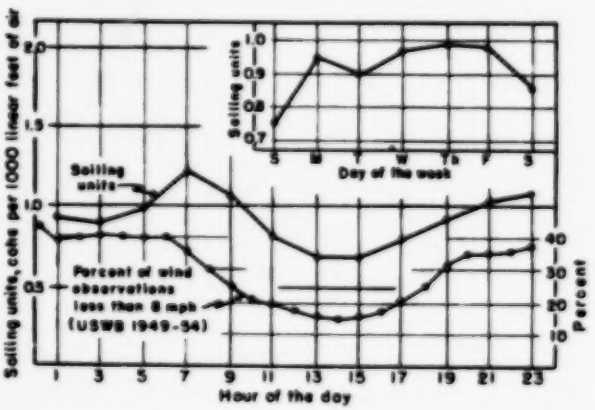


Figure 12

HOURLY AND DAILY VARIATIONS OF
SOILING UNIT VALUES
(State Board of Health Station)
(April 1958 - March 1960)



UNIVERSITY OF MINNESOTA

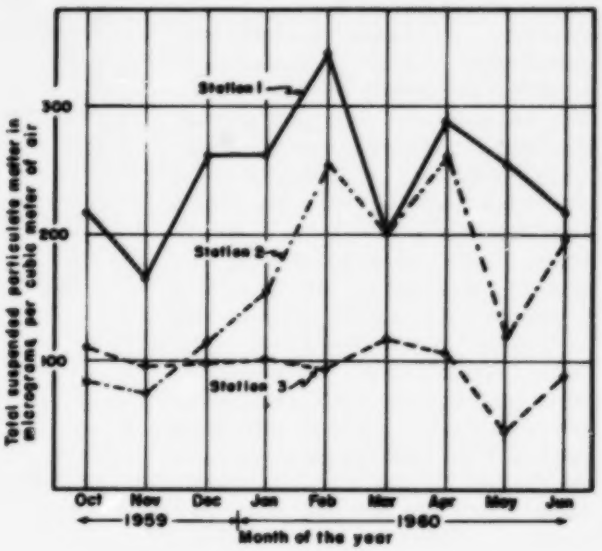
The School of Public Health of the University of Minnesota is currently engaged in an investigation of the possible relationship between emissions from the grain industry and occurrence of asthmatic attacks among students. In connection with the grain industry-asthma study, air sampling is employed. Current

findings of the sampling program which started in 1959 are presented here.

High-volume air samplers are located in the grain mill area and on the university campus. At station 1 in the industrial area around the grain mills, suspended particulate loadings are much higher than at stations 2 and 3 in the campus area (Figure 13). Station 3 is farthest from the mill area. This contrast would be typical of many industrial versus residential comparisons. Concentrations of suspended particulate matter at stations 1 and 2 are considered quite high.

Figure 13

SUSPENDED PARTICULATE CONCENTRATIONS
(grain industry - asthma study)



Dustfall jars are located throughout the study area, and pilot studies with the use of greased microscope slides have been conducted. Analyses of the collected dust samples at two stations for over one year showed concentrations in the industrial area to be about 50 per cent higher than on the university campus. The organic fraction averaged 29 per cent of the campus sample and 46 per cent of the industrial sample.

Air samples are collected during consecutive two-hour periods with an automatic sequential sampler to determine background levels of sulfur dioxide. The West-Gaeke method was used for analysis (75). The 90 percentile reading (90 per cent of the values are less than the reading) for sulfur dioxide was seven parts per hundred million parts of air by volume in February and March, but decreased to one-tenth of this value in early summer (Table XV). These data do not indicate existence of a severe sulfur dioxide pollution problem.

TABLE XV
Ninety Percentile Value of Sulfur Dioxide
Grain Industry - Asthma Study
SO_2 in Parts per Hundred Million Parts of Air by Volume
(1959-1960)

Dec.	Jan.	Feb.	Mar.	Apr.	May	June
2.4	4.8	7.3	7.4	1.9	0.6	1.0

LOCAL GOVERNMENTS

Limited air sampling has been done by and for local governmental agencies. In 1947, surveys of heating and power plants in Minneapolis and St. Paul were made by the Coal Producers Committee for Smoke Abatement (36,37). The reports on these surveys recommended that "sootfall" studies be made to determine the extent of air pollution. Dustfall measurements have been made at 13 stations in St. Paul since 1947, but data for Minneapolis are not available. The overall annual average dustfall in St. Paul according to these records has decreased by one-third over the 13-year span to about 22 tons per square mile per month (Figure 14). During the same period the combustible portion decreased 50 per cent to about five tons per square mile per month. These reductions reflect the change in fuel used by railroads and for space heating in St. Paul. Present average dustfall values do not indicate a severe generalized dustfall problem.

Figure 14

AVERAGE DUSTFALL IN ST. PAUL

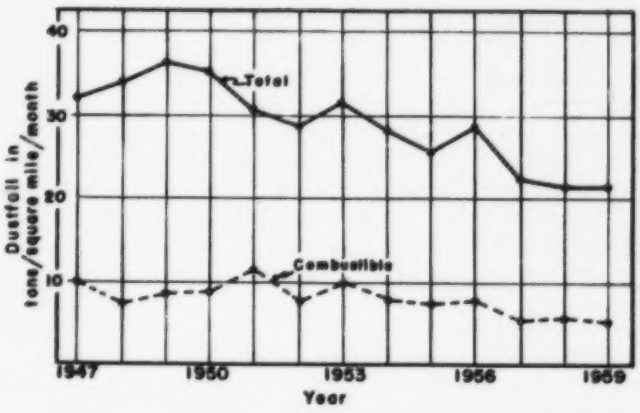
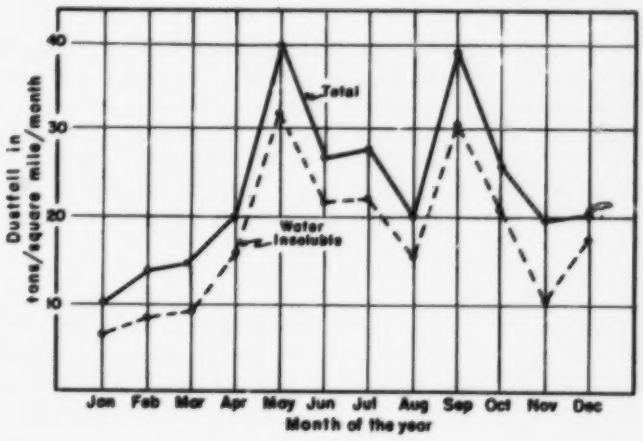


Figure 15

MEDIAN DUSTFALL FOR EIGHT STATIONS IN HOPKINS - 1951



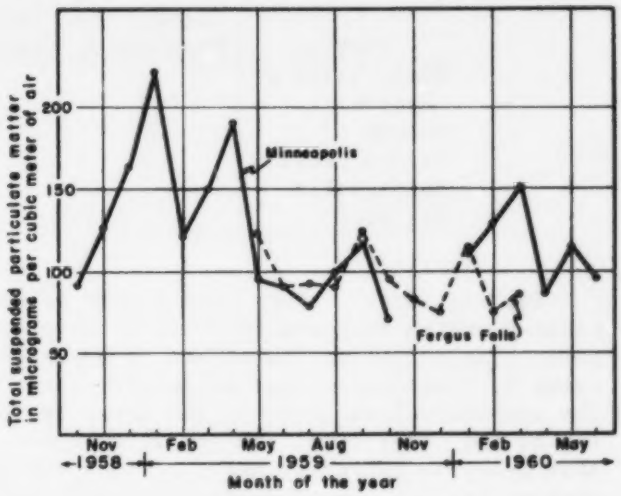
During the calendar year 1951, the State Department of Health conducted a dustfall study in the city of Hopkins. The median monthly dustfall for eight sampling stations ranged from ten to 40 tons per square mile per month, with the highest values occurring in May and September (Figure 15). The overall average for the year was 20 tons per square mile per month. Dustfall in the industrialized area averaged 37, with a maximum value of 54 tons per square mile per month.

In the fall of 1958, the city of Minneapolis purchased a high-volume air sampler similar to those used by the National Air Sampling Network. Since that

time samples have been collected once a week in downtown Minneapolis. Results of sampling show that the highest monthly average suspended particulate concentrations occur during the winter months (Figure 16) and that undesirably high pollution levels occur from time to time. A limited amount of data was collected simultaneously in residential Minneapolis showing concentrations less than half of the downtown values.

Figure 16

SUSPENDED PARTICULATE CONCENTRATIONS
(Minneapolis and Fergus Falls)



In the spring of 1959, local authorities in Fergus Falls became interested in establishing a base line of pollution load in the air before a power plant proposing to burn pulverized lignite began operating. With consultation from the State Department of Health, dustfall jars were set out in the community. A low-volume tape air sampler was made available by the state for periodic use. A high-volume air sampler was purchased. Monthly average suspended particulate concentrations are quite low (Figure 16).

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SPECIAL SAMPLING PROGRAM

At the start of this survey it was recognized that existing data on air contaminants were limited and that they should be supplemented. With cooperation of personnel from Minneapolis, St. Paul, Duluth, and Fergus Falls, arrangements were made to sample simultaneously for three two-week periods at one station in each of these communities and at the State Board of Health station. A high-volume sampler and a low-volume tape sampler were used at each of these stations during the periods October 26 - November 8, December 15 - December 29, and February 8 - February 22. Dustfall jars also were set out at each station the first of each month from October through April. Automatic gas sampling equipment was operated at the State Board of Health station. Two-hour samples were analyzed for sulfur dioxide, nitrogen dioxide, and ozone.

Average suspended particulate matter concentrations were low and were remarkably similar in the four cities during the fall sampling period (Table XVI). During the December and February sampling concentrations were generally higher, but a pattern was not established. Particulate loadings appear to be related to the size of the community, with Minneapolis-St. Paul loadings generally being highest, a reflection of the greater concentration of pollution sources in the larger communities.

TABLE XVI
Suspended Particulate Concentrations
Micrograms per Cubic Meter of Air
(1959-1960)

Station	October 26-November 8	December 15-December 29	February 8-February 22
State Board of Health	60	80	110
Duluth	68	60	82
Fergus Falls	69	83	46
Minneapolis		84	98
St. Paul	67	119	118

Soiling index values were higher in Fergus Falls and Duluth than at the other sampling stations, reflecting the greater use of solid fuels for heat and power (Table XVII). The effect of emissions from space heating units is indicated by generally higher values obtained during the last two sampling periods. The average values given in the table are considered moderate to heavy, according to one adjectival rating system (38). The 90 percentile values indicate that heavy to extremely heavy soiling occurs ten per cent of the time. These shorter periods are of particular concern from an air pollution standpoint.

TABLE XVII
Soiling Unit Values
COHS per 1,000 Linear Feet of Air*
(1959-1960)

Station	October 26-November 9			December 14-December 31			February 8-February 25		
	Avg.	90 percentile	Max.	Avg.	90 percentile	Max.	Avg.	90 percentile	Max.
State Board of Health	0.8	1.7	2.7	1.2	2.2	6.0	1.2	2.6	4.0
Duluth	1.4	2.6	9.6	1.5	3.3	10.0	1.9	3.7	8.2
Fergus Falls	1.9	3.3	6.0	2.8	5.1	8.5	1.9	2.1	5.8
Minneapolis	1.4	2.3	3.3	1.6	3.0	5.5	1.2	2.1	3.2
St. Paul	1.6	3.2	4.7	1.4	2.8	5.2	1.1	1.9	3.2

*0-0.9 considered light, 1-1.9 moderate, 2-2.9 heavy, 3-3.9 very heavy, and greater than 4 extremely heavy (38)

The dustfall jars were set out the first day of each month and left there until replaced the first day of the following month. The heaviest dustfall was noted in five of the six months at the State Board of Health station (Table XVIII). This may be attributed to the station's location with reference to the grain industry, the river terminal coal docks, the university's power plant, and the campus building incinerators. The high November dustfall

TABLE XVIII
Dustfall
Tons per Square Mile per Month
(1959-1960)

Station	November	December	January	February	March	April
State Board of Health	40	34	63	75	66	32
Duluth	29	19	21	21	49	
Fergus Falls	54	20	15	10	16	
Minneapolis downtown		10	21	20	24	25
Minneapolis residential		- - 10 - -		7	11	13
St. Paul	18	10	13	14	43	29

value for Fergus Falls is likely the result of dust storms prevalent in the area during the sampling period. Values above 25 tons per square mile per month probably indicate dustfall rates higher than desirable (59). Since sampling was done only during the winter months, a seasonal pattern was not obtained.

From a comparison of the data in Tables XVI, XVII, and XVIII, it is interesting to note that, while the highest dustfall occurred at the State Board of Health station, the highest suspended particulate concentrations were found at the St. Paul station and the highest soiling units were found at the Fergus Falls station. This indicates that the prime sources of pollution vary at the different stations.

Table XIX shows the average, 90 percentile, and maximum concentrations of sulfur dioxide, ozone, and oxides of nitrogen measured during successive two-hour samplings during three two-week periods at the State Board of Health

TABLE XIX
Gas Concentrations
State Board of Health Station
Parts of Gas per Hundred Million Parts of Air by Volume
(1959-1960)

	November 2-November 18			December 15-December 25			February 8-February 23		
Pollutant	Avg.	90 percentile	Max.	Avg.	90 percentile	Max.	Avg.	90 percentile	Max.
Sulfur dioxide	1.7	3.7	9.8	2.9	5.3	15.0	4.0	9.7	25.1
Ozone	1.4	2.6	39.0	0.3	0.6	1.0	0.4	0.6	9.6
Nitrogen dioxide	0.4	0.6	1.2	0.8	1.2	2.7	0.7	1.2	1.8

station. These are the only data available on gaseous air contaminants in Minnesota. Generally, sulfur dioxide levels are highest during colder parts of the heating season (December through February, see Figure 11) because more fuel containing sulfur is burned during colder weather than at other times. Nitrogen oxides are emitted from many combustion processes and therefore concentrations are higher during the colder weather. The ratio between average values for the December and February sampling periods and the November sampling period is 2.5 to 1 for sulfur dioxide and 1.9 to 1 for nitrogen oxides. The sulfur dioxide ratio is high because pollution emissions (and hence ambient air concentrations) are influenced almost entirely by rate of coal and fuel oil use. The nitrogen oxide ratio is lower because this pollutant is also emitted by motor vehicles whose use is somewhat greater during the summer months.

Ozone in the air occurs naturally and as a photochemical reaction product of certain hydrocarbons and nitrogen oxides. The ozone further reacts with hydrocarbons to form other products and probably also reacts with sulfur dioxide, both processes tending to reduce ozone concentrations. The rate of formation of ozone is related to intensity of sunlight. Thus, the higher ozone values in November as compared with December and February seem logical.

These data give some measure of pollution concentrations, but further sampling is needed to determine the significance of gaseous contaminants in terms of local environmental factors. The West-Gaeke method (75) was used for the determination of sulfur dioxide, the alkaline potassium iodide method (76) for ozone, and the Jacobs-Hochleiser method (77) for nitrogen oxides.

WEATHER AND TERRAIN

ABSTRACT

Minnesota's weather and terrain are generally favorable for dispersion of air pollutants. A large part of the state is level or gently rolling, a situation favorable to good air circulation and thus dispersion of air pollutants. However, there are a number of communities located in valleys where dispersion of pollutants is restricted by the physical presence of valley walls and where the wind speed is lower than that found on hilltops or on level terrain. Average wind speed is high enough throughout the state to provide for good dispersion of pollution most of the time, except in a few valley locations. However, periods of low wind speed do occur and, at such times, pollution levels will be above normal.

Vertical mixing in the atmosphere is minimized when inversions exist. During such periods dispersion of air pollutants is restricted. Frequency of occurrence of inversions in Minnesota is neither unusually high nor low, thus placing the state at no particular advantage or disadvantage with respect to the nation as a whole.

Minnesota has long, cold winters. This makes it necessary to use a large amount of fuel for space heating. Use of fuel results in emission of pollution to the atmosphere. Therefore, Minnesota is at a disadvantage, from an air pollution standpoint, when compared with warmer parts of the country.

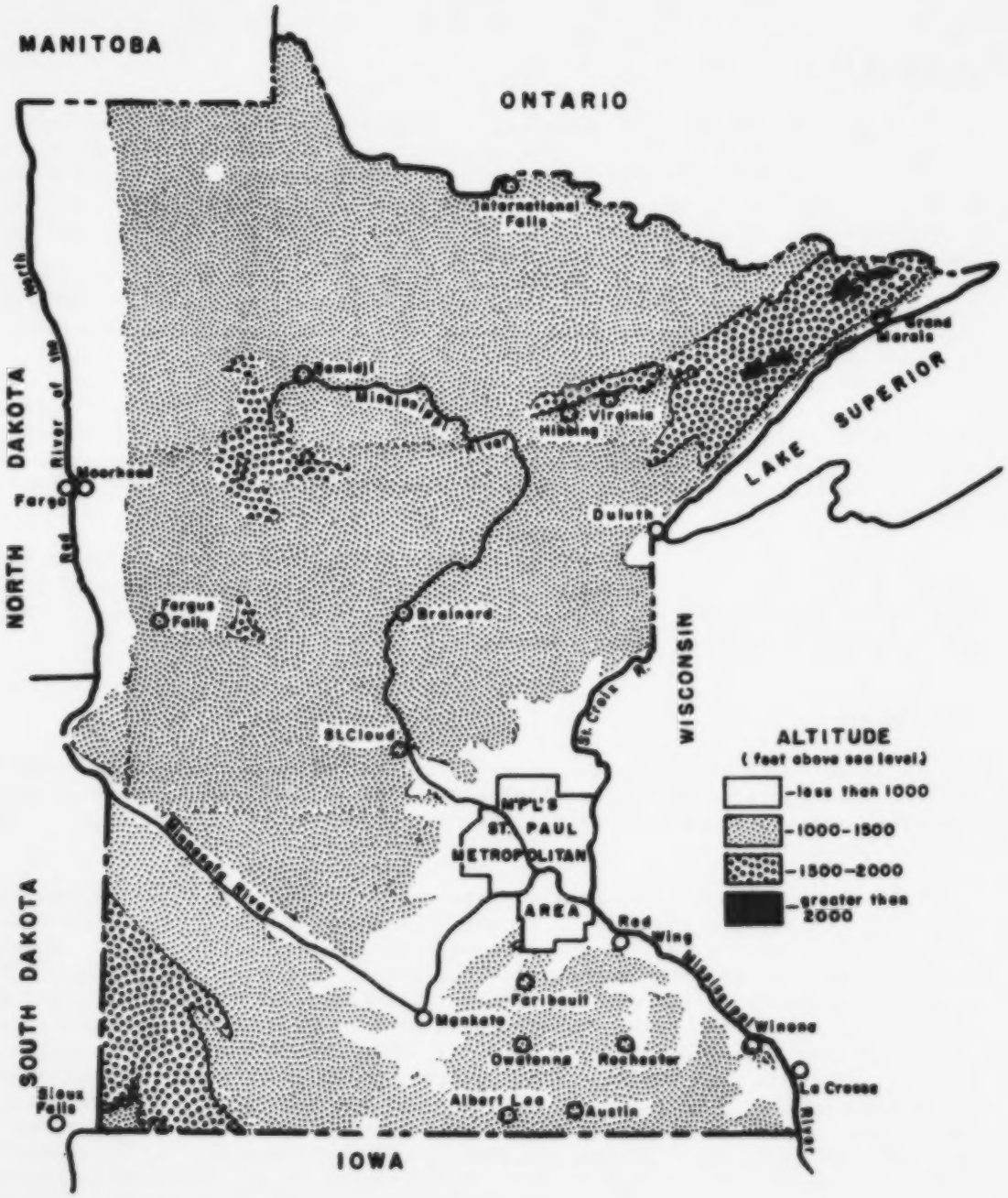
GENERAL

A large part of Minnesota's 84,682 square miles is level or gently rolling, but it has areas of considerable relief (Figure 17). Certain of these features, especially the river valleys, may increase the air pollution potential of local areas.

Minnesota, occupying the central crest of North America, has a marked continental type climate controlled by the interrelationship of the Aleutian and Icelandic low and the Pacific and Bermuda high pressure systems (41). Sharing its northern border with Canada and the great land mass extending to the Arctic, the state is subject to frequent outbreaks of continental polar air throughout most of the year. In the same sense, 400 miles to the south, warm moist air from the Gulf of Mexico overruns the southern border of the state to produce alternate warm spells. This cyclic control of climate gives Minnesota changeable weather characterized by wide variations in temperature, scanty winter but ample summer precipitation, and a general tendency for extremes in all climatic features. Storms originating in northwestern or southwestern United States migrate eastward through the state to be followed by cooler, sometimes much colder, polar air masses from the northwest or north. Because

Figure 17

TOPOGRAPHY OF MINNESOTA (40)

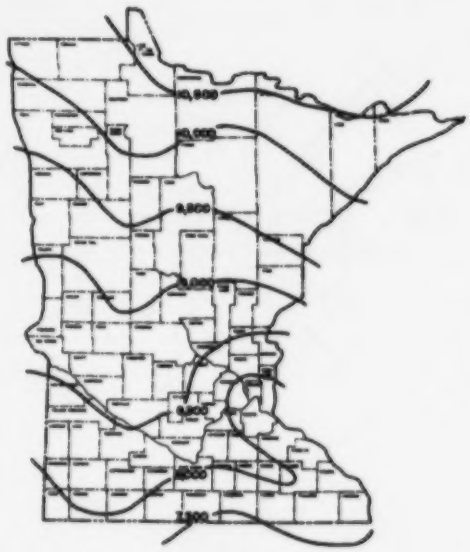


of the absence of major physiographical features, climatic conditions throughout the state on any one day tend to be modified in the main by the temperature extremes of the 400-mile north-south dimension.

Seasonal temperature differences are great, ranging from very warm though comfortable (due to low daytime humidity) in summer to very cold in winter. The average mean temperature for the four seasons for the period 1931 - 1955 was: winter 14°F, spring 42°F, summer 68°F, and fall 46°F. A temperature differential of 15°F or more is normal between widely separated areas of the state. Temperature can also be expressed in terms of degree days, which are a measure of the departure of the mean daily temperature from a given standard. If the degree days are accumulated over a "season", the total can be used as an index of space heating fuel requirements. Annual heating degree days (65°F base) for Minnesota communities vary from 7,500 to over 10,500 (Figure 18) (30,42). For comparison purposes, Chicago has 6,310 degree days, New York 5,050, San Francisco 3,069, Atlanta 2,826, and Los Angeles 1,451 (3).

Figure 18

ANNUAL DEGREE DAYS-65°F BASE
(Period 1921-1950) (30)



The annual average surface wind speed at various weather stations throughout the state is a little over ten miles per hour (Table XX). Wind speeds in several

TABLE XX
Prevailing Direction and
Mean Hourly Speed* of Wind (43)

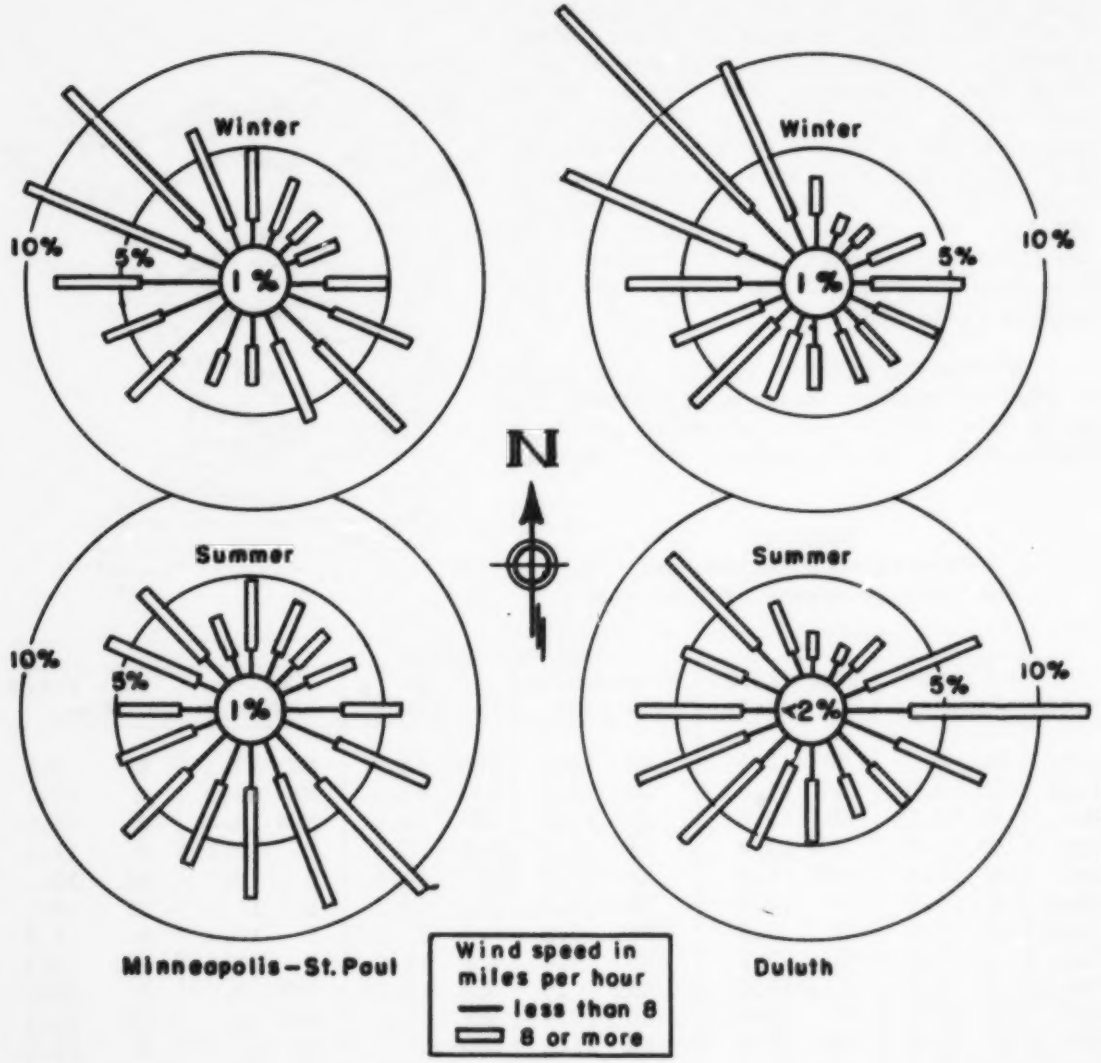
Month	Weather station					
	LaCrosse Wisconsin	Sioux Falls So. Dakota	Minneapolis St. Paul	Fargo No. Dakota	Duluth Minn.	Intl. Falls Minn.
Jan.	NW 8.7	NW 11.3	NW 10.6	NNW 13.6	NW 12.3	W 9.5
Feb.	NW 8.8	NW 11.3	NW 10.9	NNW 13.4	NW 13.2	W 10.1
Mar.	NW 10.2	NW 12.8	NW 11.6	NNW 13.9	WNW 13.4	W 10.0
Apr.	NW 11.8	NNW 13.4	NW 12.7	NNW 15.3	E 15.1	W 11.8
May	S 10.8	SSE 11.9	SE 11.6	N 14.3	E 13.7	NW 10.7
June	S 9.1	S 10.6	SE 11.1	SSE 12.8	E 11.6	SE 9.1
July	S 7.6	S 9.3	SE 9.5	S 11.3	E 10.7	W 8.0
Aug.	S 7.1	S 9.1	SE 9.4	SSE 11.8	E 10.6	SE 7.7
Sept.	S 8.8	S 10.2	SSE 10.5	SSE 13.1	WNW 12.2	W 10.0
Oct.	S 10.0	S 11.0	SE 10.9	SSE 13.6	WNW 12.7	SE 10.3
Nov.	S 11.5	NW 12.5	NW 11.6	NNW 14.6	NW 13.9	W 11.6
Dec.	S 9.5	NW 11.0	NW 10.8	S 13.4	NW 12.5	W 9.7

*Miles per hour

sections of the nation average less than ten miles per hour. The table shows that spring winds tend to be higher and summer winds tend to be lower than the annual average and that the prairie sections of western Minnesota have wind speeds above the state average. Seasonal wind roses for Minneapolis-St. Paul and Duluth (Figure 19) give a pictorial representation of the percentage of time the wind blows from each of the 16 points of the compass, based on hourly readings for the 1949 - 1954 period. They are drawn to show total winds and

Figure 19

PER CENT FREQUENCY OF WIND DIRECTION (44,45)

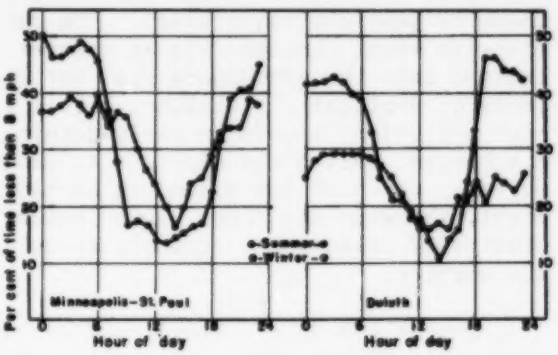


Per cent calm given in center circle

the portion having a velocity of less than eight miles per hour. They show that the predominant wind is from the northwest in winter, but from the southeast (for Minneapolis-St. Paul) and east (for Duluth) in summer. Winds from the northeast are least prevalent during all seasons of the year, which suggests that there might be some wisdom in locating sources of air pollution in this direction from urban centers. Air pollution is typically most severe during periods having low-velocity winds. Low-velocity winds are more prevalent at night; during July and August nighttime winds of less than eight miles per hour prevail during more than 50 per cent of the time (Figure 20).

Figure 20

HOURLY FREQUENCY OF WIND SPEEDS LESS THAN EIGHT MILES PER HOUR (44,45)



Energy received from the sun at the surface of the earth by day is re-radiated in the form of heat from the earth by night. During nighttime hours, ground temperature drops and air near the earth surface is cooled by contact with the earth. Thus, air near the ground is cooler and heavier than the warmer air above. This regime is known as a nocturnal or radiation inversion (Table XXI). If winds are strong, turbulence will prevent establishment of an inversion. Radiation inversions do not occur on cloudy nights, since the clouds prevent radiative cooling of the earth's surface. Nocturnal or radiation inversions are usually, though not always, dissipated by surface heating (earlier

TABLE XXI
Percentage Frequency of Inversion Categories (46)

Season	Time CST	Cases	Inversion category* per cent of cases				
			A	B	C	D	E
Winter (1948-1952)	2100	306	28	18	52	1	1
	0900	310	24	11	63	0.3	1
Summer (1940-1944)	2100	243	37	23	21	6	12
	0900	182	2	1	53	10	35

*See page 45 for definition of inversion categories

All summer inversion data were obtained from records at St. Paul for the months of July and August in the period 1940-1944.

All winter inversion data were obtained from records at St. Cloud for the months of December and January in the period 1948-1952.

Maximum number of cases possible is 310.

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in the day in summer than in winter) and by the normal increase in wind velocity after sunrise. These temperature inversions are common in all seasons in Minnesota (as in many parts of the nation) but are more frequent in winter. In summer, nighttime surface-based inversions (involving air depths extending down to the ground surface) occur on nights when the sky is relatively clear and winds are light. When an inversion exists, vertical mixing in the atmosphere is severely restricted. The cool, heavy air near the surface does not mix with warm, lighter air at greater elevations. Therefore, pollutants discharged into the atmosphere are not dissipated vertically because of the absence of vertical circulation. This is an important factor contributing to high pollution levels in early morning hours: an accumulation of pollutants discharged during the night. As soon as solar heating warms the earth's surface, air near the ground is heated by contact with the warm earth. Being light, the warm air rises, thus establishing vertical mixing which usually dissipates pollutants accumulated during the night by nine or ten o'clock in the morning.

Deeper and more intense surface-based inversions that occur in winter are attributed to the effect of strong radiational cooling and to stability intensification from the higher atmosphere by subsidence within the high pressure Arctic air masses common to this area (Table XXII). Also, longer periods of consecutive hours of inversion are more probable during the fall and winter seasons when the area is dominated by subsidence inversion (main inversion) associated with slowly moving Arctic air masses. These involve stable (limited vertical mixing) layers (depths) of air that do not extend down to ground level.

TABLE XXII
Average Height (Meters) of Surface-Based Inversion Tops and Main Inversion Bases (46)

Season	Time CST	Surface-based inversion (category A)*		Surface-based inversion with main inversion (category C)*				Main inversion (category B)*	
		Top		Surface-based inv. top		Main inv. base		Base	
Winter (1948-1952)	2100	866	(84)**	350	(54)	895	(54)	524	(161)
	0900	936	(75)	418	(35)	1056	(35)	405	(196)
Summer (1940-1944)	2100	329	(90)	232	(56)	1352	(56)	1081	(53)
	0900	229	(2)	115	(1)	595	(1)	946	(96)

*See page 45 for definition of inversion categories
**Figures in parentheses are the number of cases

All summer inversion data were obtained from records at St. Paul for the months of July and August in the period 1940-1944.

All winter inversion data were obtained from records at St. Cloud for the months of December and January in the period 1948-1952.

Maximum number of cases possible is 310.

At times main inversions are destroyed only by the passage of a new weather system. On the average, about eight low pressure systems will migrate across the state each month. In the winter the number will be above average, perhaps ten or 12, which suggests that a stagnation period of more than three days during winter months would be unusual. In the spring the prevalence of relatively high winds reduces the possibility of periods of inversion lasting one or more days.

The presence of fog usually limits solar heating and affects the degree of vertical circulation in the lower layers of air. Under these circumstances inversion periods tend to be prolonged. Air pollution may have a similar effect on weather, in that it provides condensation nuclei for formation of fog. Heavy fogs (visibility less than one-fourth mile) occur about ten to 20 times per year for the state as a whole, and it is unusual for them to last 24 hours. However, along the north shore of Lake Superior they occur three times as often and are likely to be of longer duration.

Severe air pollution episodes have been associated with low wind velocities, temperature inversions, and condensation forms (fog, rain, etc.). The simultaneous occurrence of these conditions for brief periods is not a particularly rare phenomenon, especially in hilly country. If these conditions were to persist for several days at certain places in Minnesota, objectionably high air pollution levels would occur.

LOCAL

Certain features of the face of Minnesota (39) influence the air pollution potential of local areas.

The area immediately north of the Minnesota River, which includes about one-third of the state, is an outstanding example of ground moraine left in the wake of a glacier. The gently rolling plain, interspersed in a patternless fashion with recessional and terminal moraines that rise 50 to 400 feet above the general level of the land, makes for a rugged landscape with many rounded hills, lakes, ponds, and bogs. Most communities in this area are located on relatively flat outwash plains or gently rolling moraine areas where weather is favorable to the dispersion of contaminants. However, a few cities, such as Fergus Falls, are nestled in valleys which would modify the general weather pattern of the area as a whole in a manner detrimental to dispersion of air pollution.

. . . . . .

*Inversion Category Definitions

A Surface-based inversion; no other inversion below 2 kilometers (6,562 ft.).
B Main inversion; above surface but below 2 kilometers; no other inversion existent.
C Surface-based inversion concurrent with main inversion.
D Inversion based above 2 kilometers and below 500 millibars (18,300 ft.).
E No inversion below 500 millibars.

Many communities, comprising five to ten per cent of the outstate population, are located in river valleys where dispersion of air contaminants is less rapid.

The Minnesota River flows in the valley formed by the discharge of glacial Lake Agassiz. This valley varies from one to five miles in width and from 75 to 200 feet in depth. The overall drop in elevation of the river from Big Stone Lake to its junction with the Mississippi is about 270 feet. The terraces of the old river serve as sites for many communities, including Shakopee, Chaska, Le Sueur, St. Peter, Mankato, New Ulm, Redwood Falls, Granite Falls, Montevideo, and Ortonville.

The Mississippi River north of its junction with the Minnesota River flows mainly on glacial drift. Downstream from the junction of the two rivers (below Minneapolis and St. Paul) a deep gorge has been cut into the bedrock formations where the valley floor is 400-500 feet below the general level of the plain. This gorge is from two to four miles wide. Some of the major cities located in the Mississippi Valley are Hastings, Red Wing, Lake City, Wabasha, and Winona. Stillwater and Bayport are located on the St. Croix River, which forms part of the Minnesota-Wisconsin boundary. Local conditions for dispersion of pollution in these communities are adversely affected by their location in river valleys.

Climatological review of observations taken along the Big Sioux River near Sioux Falls in southeastern South Dakota suggests that even a small valley, 158 feet deep and about one mile wide, is a sufficiently important physiographical feature to modify wind and temperature above and within it (47). Intense inversion conditions of 12 hours or longer were shown most likely to occur during the months of September to February, averaging five times per month. Through much of the year, with the possible exception of summer, intense inversions lasting for three hours or longer were experienced ten to 15 nights every month.

Local wind direction in the Sioux Falls study tended to be channeled in the direction of the valley. The valley bottom experienced lower wind speeds than the hilltop and had a considerably larger percentage of calms. At the Pathfinder power reactor site in this valley, seasonal average wind speeds, regardless of direction, are consistently lower in the valley than on nearby higher ground (Table XXIII). These findings are relevant to many of the valley communities in Minnesota.

TABLE XXIII
Seasonal Average Wind Speed* - Pathfinder Site (47)

Location	Season				Annual
	Summer	Fall	Winter	Spring	
Hilltop	8.4	10.6	10.1	11.9	10.3
Valley bottom	4.9	6.5	6.2	7.4	6.3

*Miles per hour

The Red River of the North flows through the bed of what once was glacial Lake Agassiz. The land slopes gently toward the river from the prairies in both the Dakotas and Minnesota and offers little surface friction to the winds of the area. The slight slope favors nighttime air drainage and radiation fog.

The north shore of Lake Superior rises abruptly 500-900 feet above the lake surface. This change in elevation and the presence of the lake have a modifying effect upon the weather adjacent to the lake. Occasionally in mid-summer, with a strong easterly wind off the lake, it is topcoat weather in Duluth while the heat is stifling ten miles inland from the crest of the hills. Heavy fogs, which are more frequent and of longer duration along the north shore than throughout the rest of the state, are apt to occur when warm moist air, borne by easterly winds, moves over the cool lake surface.

The Mesabi iron range is on the southern slope of the Giant's Range, which in its most easterly extension rises 500 feet above the general level of the region. This relief may reduce surface winds from the northwest and may promote nighttime air drainage in the area around Virginia.

International Falls, at the Canadian border, lies in generally level terrain. Approximately 30 per cent of the area to the north and northwest is lake surface, which provides much moisture for local late afternoon and evening showers and also serves as a reservoir for heat that tempers the cold air flowing in from the north in September and October. The lakes and forest area tend to reduce daytime - nighttime temperature differences, but they also reduce wind turbulence.

The Coteau des Prairies of the Dakotas cuts across the southwestern portion of the state with an elevation approaching 1,900 feet. To the northeast these hills drop off rather rapidly to a rolling plain and then drop again to the broad valley of the Minnesota River. Dispersion of pollutants from this area is favorable, since winds are high and no valleys or basins exist where pollution could be trapped.

POPULATION

ABSTRACT

Air pollution is related to the activities of man. As population or population density increases there is more industry, more fuel used for heat and power, more car exhaust and more refuse burned. Minnesota experienced a 14.5 per cent increase in population during 1950-1960. It is estimated that the population will exceed four million before 1975 and five million before the year 2000.

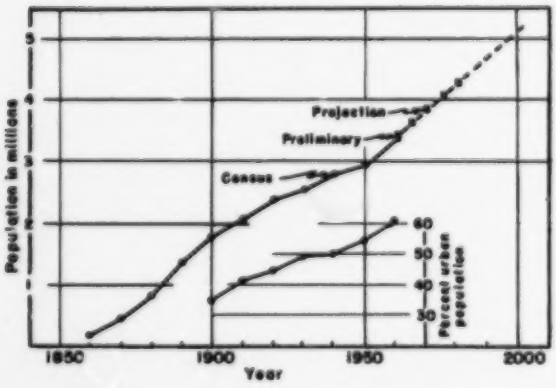
Most of the growth in the last decade occurred in urban communities. With continued growth in urban areas the problem of air pollution will be intensified unless steps are taken to control existing sources and to prevent new sources from becoming serious offenders.

GENERAL

The 1960 population of Minnesota was 3,393,302 according to preliminary census figures (48). This is a 13.8 per cent increase from 1950 (Figure 21). (Minnesota's official 1960 population was 3,413,864, a 14.5 per cent increase from 1950.) The national increase for the same period was 14.7 per cent. Population projections predict a growth to four million before 1975 and to five million before the year 2000. The shape of the population growth curve shows that Minnesota shared in the flood of European immigration in the latter part of the nineteenth century which brought millions of people into Midwest America. With the turn of the century the curve shows a marked decline in growth rate. Many rural districts suffered substantial losses in population, and gains in the urban centers were not sufficient to maintain the overall growth rate. In 1956 a long-time trend of out-migration from the state was reversed (49). The pattern of migration for Minnesota appears to be related to the comparative economy of the state and the nation.

Figure 21

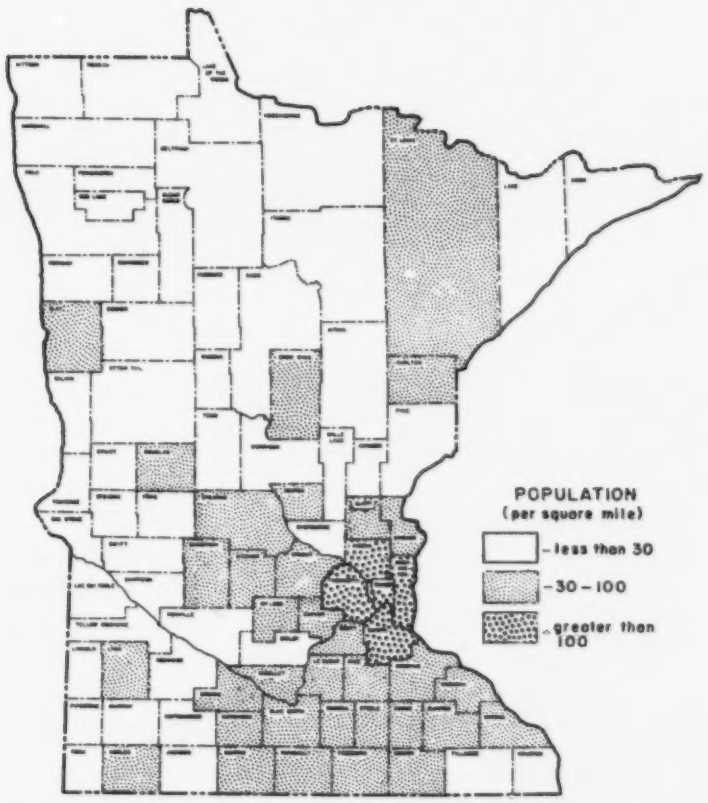
POPULATION INCREASE IN MINNESOTA (3,48)



In the early 1940's the urban population equaled the rural population. By 1960, 61 per cent of the state's population lived in communities of more than 2,500 persons (Figure 21). During the 1950's the decline in certain rural areas

Figure 22

POPULATION DENSITY BY COUNTY
1960 (48)



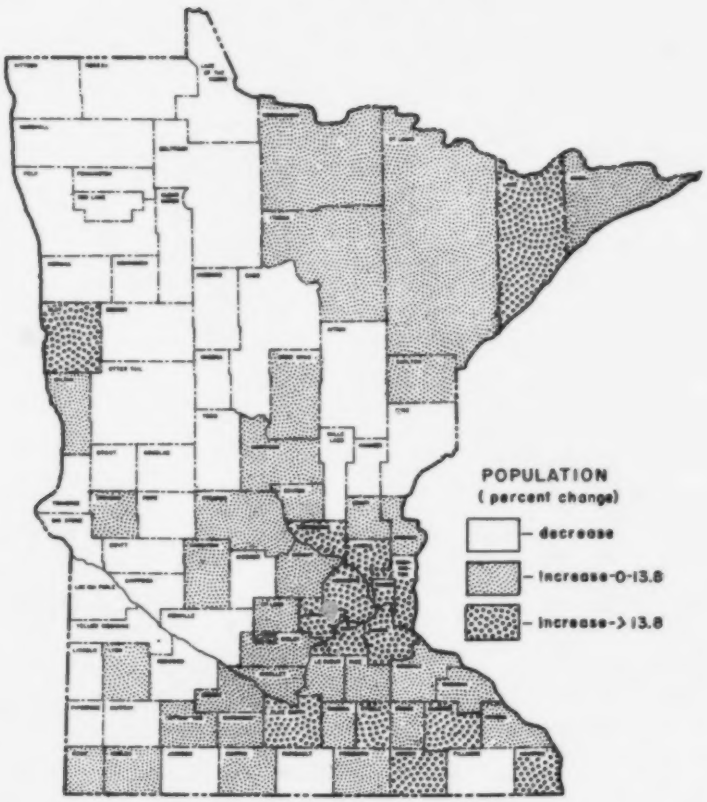
continued,but the accelerated growth in several of the urban centers more than offset these losses. The greatest rate of growth during the 1950-1960 decade occurred in counties with the greatest population density (Figure 22).

Of Minnesota's 87 counties, 39 decreased in population, while only 15 had a growth greater than the state average of 13.8 per cent for this period (Figure 23).

The greatest growth and concentration of population occurred in the Minneapolis-St. Paul Metropolitan Area. Preliminary 1960 census figures show that this Standard Metropolitan Area (SMA), made up of five counties (Anoka, Dakota, Hennepin, Ramsey, and Washington), was the fourteenth largest in the United States (50). These data also show that 45 per cent of the state's population lives in the seven county Metropolitan Planning Area (MPA) (SMA plus Carver and Scott counties) and that 81 per cent of the state's growth from 1950 to 1960 occurred in the MPA. "About the middle of June 1959, the population of the MPA passed the 1 1/2 million mark.- - - By 1980 the area will have

Figure 23

POPULATION CHANGE BY COUNTY
1950 - 1960 (48)



added over 800,000 additional people for an estimated population of 2,320,000" (51). Most of this growth will take place outside the political boundaries of the central cities.

This population picture reveals that the state is growing at a rate somewhat less than the national average,but,if the migration trend of recent years continues, this ratio may be reversed. The state is becoming more urbanized, with the greatest growth taking place in the counties with the greatest population density. Lake county, whose growth reflects the development of the taconite industry during the last decade, is an exception to this pattern.

The concentration of population in urban areas results in the creation of greater industrial and distribution centers. As communities increase in population and in industrial and commercial activity, use of fuels for space heating and transportation and waste disposal operations also increases. All of these activities result in emissions of pollutants and, therefore, the need for pollution control will become greater.

LEGISLATIVE PATTERNS

ABSTRACT

Cities in Minnesota are authorized by law to regulate emission of dense smoke. They also are empowered to control nuisances. Because of this limited scope and because of existing interjurisdictional problems, enabling legislation is inadequate to serve the needs of many local communities. The power of local communities should be broadened and the flexibility of the law should be increased to cope with the changing pattern of the air pollution problem.

The State Board of Health has authority to make regulations regarding "atmospheric pollution which may be injurious or detrimental to public health," but the state agency responsible should have authority to consider all other aspects of air pollution. Primary responsibility for the control of air pollution should be at the local level, but the state agency should be in a position to render the technical assistance necessary to the many communities that do not have the financial resources to provide technical personnel or whose problems may not warrant the full-time services of such personnel.

GENERAL

The goal of air pollution legislation should be to maintain a reasonable degree of purity of our air resources consistent with: a) public health, comfort, and welfare; b) protection of plant and animal life; c) protection of physical property and other resources; d) visibility requirements for safe air and ground transportation; and e) continued economic development and growth.

At all levels of government, air pollution control can be most effectively brought about by reasonable legislation based on technically-substantiated criteria. It should provide adequate flexibility, yet be reasonably specific to meet the needs of the area under consideration.

Present laws in Minnesota, both at the state and local level, are limited in scope and do not adequately meet present and future needs.

LEGISLATION IN MINNESOTA

Existing Minnesota state legislation enacted at different periods is abstracted below.

Control Legislation (Limited)

Section 144.12 of Minnesota Statutes (1953) as amended (1957) authorizes the State Board of Health to make regulations regarding atmospheric "pollution which may be injurious or detrimental to public health." Such regulations

have the force of law except insofar as they conflict with any statute or with the charter or ordinance of a city of the first class. The Board may require licenses or permits to achieve its purpose of regulation.

Enabling Legislation

Chapter IV, Section 5, page 29 of the Minneapolis City Charter (as amended to July 1, 1959) authorizes the City Council to regulate the construction of buildings, chimneys, and stacks within the limits of said city, also the emission of dense smoke; it has authority to prohibit and prevent the erection or maintenance of any insecure or unsafe buildings, stacks, walls, or chimneys and the emission of dense smoke in said city, to declare them to be nuisances, and to provide for their summary abatement.

It has authority to enact ordinances imposing penalties upon persons or parties who may create, continue, or suffer nuisances to exist.

Chapter XXI, Section 450, page 139 of the St. Paul City Charter (as amended to October 1, 1956) empowers the Commissioner of the Public Utilities Department to abate smoke.

Under authority granted by its charter, the City of Duluth adopted an ordinance (October 12, 1931) declaring the emission of dense smoke to be a public nuisance, limiting the emission thereof, and providing for a smoke inspection department and commission.

Section 461.07-.08 of Minnesota Statutes (1957) authorizes the council or other governing body of each city in the state which has at least 20,000 but not more than 50,000 inhabitants to enact and provide penalties for the violation of ordinances to regulate the emission of dense smoke. Such ordinances may define the meaning of dense smoke and declare the emission thereof to be a public nuisance and provide effective steps for abatement.

Section 461.09 of Minnesota Statutes (1957) authorizes any city of the third class (10,000-20,000 population) to regulate the emission of dense smoke from the smoke stack of any locomotive, engine, or building, to declare such emission to be a public nuisance, and to provide for its abatement.

Section 411.40 (53) of Minnesota Statutes (1957) authorizes any city of the fourth class (under 10,000 population) to declare the emission of dense smoke from chimneys, stacks, boats, and locomotives within the limits of the city a nuisance; to prohibit and prevent the emission of dense smoke in any portion of or through the city, and to require the use, in connection with furnaces, of such practical appliances as it may designate to prevent and lessen the emission of dense smoke; and to designate the kind of fuel which shall not be used in any furnace, stove, or fireplace without the use of such appliances to prevent the emission of dense smoke.

Nuisance Statute

To the extent that air pollution constitutes a public nuisance in fact, it is subject to injunction, abatement, and penalty in an action by the state

under a general statute prohibiting nuisances. Similar action may be taken by local government units which have been delegated appropriate authority.

Such procedures, however, are cumbersome and frequently uncertain in their results, and the punitive approach is one not calculated to prevent air pollution before it occurs. These statutes make no provision for the application of engineering knowledge and technics to initial construction to control emission. Nor do they overcome the difficulties of proof involved in identifying sources of less obvious forms of air pollution.

Minnesota courts have held that the question of whether pollution of the atmosphere constitutes a nuisance ordinarily is one of fact depending on the circumstances of each particular case and no rule can be formulated which will be applicable to all cases. Some of the variables mentioned were location, nature of use, neighborhood, extent and frequency of the injury, and effect on enjoyment of life, health, and property.

LEGISLATION IN OTHER STATES

On the state level throughout the country there is a long history of sporadic activity of technical study in connection with specific air pollution problems, principally by state industrial hygiene agencies (52). Recently, however, there has been increasing interest in the organization of specific state air pollution programs explicitly authorized by statute.

The first of these laws was passed in Oregon in 1951, and provided for establishment of an Air Pollution Authority in the State Board of Health. Similar comprehensive legislation in Massachusetts and New Jersey followed in 1954. A state air pollution technical assistance and research program was authorized in California in 1955; in 1957 nine additional states (Nevada, Colorado, Delaware, Florida, Minnesota, New York, Ohio, Washington, and Hawaii) either enacted new or amended air pollution legislation. More recently Idaho, Tennessee, and Pennsylvania joined the growing number of states which have enacted some form of air pollution legislation.

The enactments of these states vary widely in terms of authority and approach. The more recent statutes have usually embodied one or more of the following:

a) a state-wide air pollution control program, limited in some cases, concerned with the prevention and abatement of air pollution problems;

b) a broad enabling act permitting the establishment of air pollution control districts at local option; or

c) a state research and technical assistance program.

PRINCIPLES FOR AIR POLLUTION LEGISLATION

The development of air pollution control legislation is largely a problem of the specialized application of accepted principles of administrative law

(53). As in most cases where the administrative law approach has been applied, the efficacy of a particular program depends on many extra-legal elements such as administrative personnel, size of appropriation, and public understanding.

In principle, the solution of local problems by local government should be encouraged; municipal and other local agencies should be authorized to establish control programs; and regional control should be authorized where a need is shown. The state agency should, however, be able to take action in the absence of, or the failure to act of, a local or regional authority.

In the light of the above considerations the following criteria have been adapted from the U. S. Public Health Service suggestions for legislation at the state and local levels designed to establish and carry out air pollution research and control programs. While these criteria are not all-inclusive, they are intended to provide a convenient checklist of considerations involved in the development of such legislation.

State-Wide Legislation

The air pollution control agency should be authorized to:

a) Conduct a program of research in air pollution, and to collect and disseminate information relating to air pollution and its control and prevention.

b) Establish emission standards, taking into account the purposes of the statute, current scientific knowledge, the feasibility of and the need for control; and to revise such standards from time to time.

c) Issue rules and regulations to implement the statute.

d) Conduct surveys and investigations and issue orders to abate discharges or to require remedial measures.

e) Advise, consult, and cooperate with other agencies and local authorities of the state, with other states, interstate or international agencies, and the federal government, and with affected groups and industries in the formulation and carrying out of its program; to accept and administer loans and grants from the federal government and from other sources for carrying out any of its functions; and to provide technical assistance and advice to local control organizations, industry, and other affected groups.

Local Option Legislation

The effectiveness of local option authority is enhanced when the state agency is authorized to take the necessary measures to resolve interjurisdictional air pollution problems. Local option legislation should:

a) Specify the procedure by which, and conditions under which, a district involving one or more cities or counties may be activated and

metropolitan authorities established.

b) Provide for the general and specific powers of the district, including the authority to issue rules and regulations and orders, and to enforce penalties.

c) Provide for an air pollution control board and hearing board for each district, and for the powers and duties of such boards.

d) Provide for the appointment powers and duties of officers and employees of the district, and authorize the district to carry out the purposes of the act.

e) Authorize appropriations to the districts by counties and cities comprising such districts.

f) Establish standards for the control or prohibition of obvious pollution; prohibit pollution which may be either actually or potentially harmful to persons or property; and authorize action as may be necessary during an emergency (such as may develop under adverse meteorological conditions) to require temporary curtailment of community and industrial activities which contribute to pollution.

Research and Technical AssistanceLegislation

As an alternative to a combined state-wide and local-option approach to air pollution control, an interim research and technical assistance program is appropriate. Legislation of this type should authorize the state agency to:

a) Conduct studies and research, surveys, and investigations to determine the effects of air pollution upon human, plant, and animal life, and upon materials.

b) To maintain a laboratory to provide services necessary for the furtherance of air pollution prevention and control.

c) To collect and disseminate information relating to air pollution, its causes, and the prevention, control, and abatement thereof.

d) To develop and maintain a system of monitoring the atmosphere in the state for purposes of determining the presence and quantity of air pollutants.

e) To assist local agencies by means of cooperative activities, technical assistance, and consultation for the purpose of abating and preventing air pollution.

f) To accept and administer grants from the federal government and other sources, public or private, for carrying out any of the functions indicated above.

g) To make reports to the legislature and to make recommendations for the enactment of legislation.

METROPOLITAN AREA PROBLEMS

ABSTRACT

Metropolitan areas have the most complex air pollution problems in the state. In the Minneapolis-St. Paul Metropolitan Area there are 250 governmental units, and the number is increasing. Since air pollution does not recognize political boundaries, frequent interjurisdictional problems arise. Existing legislation is inadequate to meet the air pollution problem, especially regarding powers of smaller cities in the area. Air sampling has shown that air pollution in the area reaches adverse levels at times.

The Minneapolis-St. Paul Metropolitan Area, made up of five counties, is the fourteenth largest in the nation. During 1950-1960 it had a growth of 28.3 per cent. Only two of the 13 larger areas, Los Angeles and Washington, had a greater growth during this period. Such continued growth suggests that air pollution problems will be intensified unless appropriate action is taken.

Expenditures for air pollution control lag behind cities of comparable size. In 1956 the average air pollution expenditure for 46 cities was 11 cents per capita per year, compared with the current expenditure in Minneapolis and St. Paul of two cents per capita per year.

The most desirable program would be one which would serve the entire metropolitan area. Such a program would provide the lowest per capita cost per square mile of coverage through efficient and economical use of specialized, costly equipment, laboratory facilities, and trained, experienced personnel. Control of air pollution sources could be realized regardless of location in the area. Such an air pollution control district could conceivably come about through voluntary arrangement of interested jurisdictions, but statutory provisions for cooperative services involving all jurisdictions affected by a common problem are generally more satisfactory.

Duluth, with a population of more than 100,000, has considerable potential for growth. Terrain and weather features place certain limitations on the dispersion of pollution in this community. Duluth has a smoke ordinance which was adopted in October 1931, but for approximately the past 15 years, funds have not been appropriated for the smoke inspection department, thus nullifying the intent of the ordinance. In view of the nature and frequency of complaints received, the potential expansion of industrial activity in the area, and the likely possibility of an interstate problem occurring, the local political jurisdiction should initiate control activities to reduce present air pollutants and maintain a satisfactory air environment.

MINNEAPOLIS-ST. PAUL

The Twin Cities of Minneapolis and St. Paul are located respectively in Hennepin and Ramsey counties in the southern part of the state near Wisconsin. It is here that the Mississippi and Minnesota rivers join. The metropolitan area is made up of five counties having a total area of 2,111 square miles (Table XXIV). The terrain varies little except in the extreme eastern part and for the narrow, sharply defined river valleys. The weather generally is favorable for dispersion of pollutants.

Population

In 1900, there were 460,000 persons in the Minneapolis-St. Paul Metropolitan Area; by 1950 the area had over one million persons. Preliminary figures for 1960 indicate that close to one and one-half million people live in Hennepin, Ramsey, Anoka, Washington, and Dakota counties (Table XXIV). Population projections for the five-county area for 1975 average 1,940,000 people (54).

TABLE XXIV
Population and Area of Counties in the Minneapolis-St. Paul Metropolitan Area (48)

County	1960 Population	Area sq. mi.
Hennepin	839,678	565
Ramsey	421,998	160
Anoka	85,757	425
Washington	51,700	390
Dakota	77,947	571
Total	1,477,080	2,111

Manufacturing

Over 65 per cent of both the manufacturing employment and the value added by manufacturing in the state were contained in the Minneapolis-St. Paul Metropolitan Area in 1958. The dollar value of manufacturing grew nearly half again as fast in Minnesota between 1954 and 1958 as the national average. In these four years the value added to raw materials by converting them into finished products in Minnesota plants and factories rose 14 per cent (in 1958 dollars) (55). The national average was ten per cent. Minnesota ranked twentieth in the nation in value added, at $1,995,000,000.

Since early settlement days the food processing industry has been the area's largest manufacturing employer. Food and kindred products remained the area's largest single manufacturing industry in value added in 1958 (accounting for 17 per cent), but production of machinery was a close second (6). In terms of number of employees, machinery was first. The Minneapolis-St. Paul Metropolitan Area is currently one of the top four electronic equipment manufacturing centers in the United States (56). This industry needs an environ-

ment that is not too seriously contaminated with dust or corrosive gases that might interfere with delicate components or mechanisms.

The largest industrial contributors to air pollution in the area are those dealing with food and kindred products, chemicals and products, petroleum and coal products, and primary metal industries. The area does not have a concentration of heavy industry of the type that has been a prime source of air pollution in certain other large cities.

Fuel Use

It is estimated that 80 billion cubic feet of natural gas, 130 million gallons of fuel oil, one million tons of coal, and 400 million gallons of gasoline are consumed annually in Minneapolis, St. Paul, and their immediately adjacent suburbs. This fuel consumption for heat, power, and transportation releases large quantities of contaminants to the atmosphere. It has been estimated (17) that the annual emission of pollutants from fuel burning in this area amounts to 450 million pounds (Table XXV).

TABLE XXV
Annual Emissions in the Minneapolis, St. Paul, and Suburban Area From Fuel Combustion (17)

Pollutant	Measured as	Millions of pounds of pollutants				
		Coal	Fuel oil	Natural gas	Gasoline	Total
Oxides of nitrogen	NO_2	8	6	39	8	61
Sulfur dioxide	SO_2	40	19	2	1	62
Total hydrocarbons	C_6H_{14}				26	26
Organics	--	20	5	8		33
Acids	CH_3COOH	30	14	7		51
Aldehydes	HCHO	2	1	5		8
Solids	--	200	9	1		210

Refuse Disposal

In Minneapolis, garbage is collected and incinerated by the municipality. Trash is collected by private haulers, with disposal in numerous dumps some distance away from Minneapolis. St. Paul disposes of garbage and trash primarily through sanitary landfills inside the city. St. Louis Park operates an incinerator which receives garbage and trash hauled to it by private haulers. Trash and garbage in suburban communities are usually collected by private haulers and disposed of at numerous dumps in outlying areas. Refuse disposal in the Minneapolis-St. Paul Metropolitan Area is becoming increasingly costly. New dump sites are difficult to locate, and public pressure is being applied against existing dumps because they are esthetically unacceptable. There appears to be little sentiment in favor of publicly owned sanitary landfills in the suburban area. The most likely solution to the problem seems to be the construction of incinerators in the first or second ring of municipalities surrounding the center cities.

Assuming two pounds of refuse per capita per day, three million pounds of refuse are produced daily in the area, over one billion pounds annually. Assuming one-half of this refuse is burned locally in private, commercial, or municipal incinerators and in dumps, it is estimated that some 77 million pounds of organics, 6 million pounds of solids, and 0.5 million pounds each of sulfur dioxide and ammonia are emitted to the atmosphere. Numerous complaints are received regarding smoke and odors from dump operations. Frequently they are interjurisdictional problems.

Ordinances

Minneapolis: The city of Minneapolis in 1951 passed an air pollution ordinance prescribing authority of the Division of Air Pollution Control and the duties of the chief engineer (57). The ordinance prohibits dust in combustion gases in excess of 1.5 pounds per 1,000 pounds of gases adjusted to 12 per cent carbon dioxide; smoke greater than Ringelmann No. 2 with certain exceptions; industrial emissions in excess of the maximum allowable standards adopted by the Industrial Commission of Minnesota; and emissions considered a nuisance because of certain criteria. Another ordinance (1937) regulates dust from the loading, unloading, or handling of grain. A similar ordinance pertains to coal dust.

St. Paul: An ordinance regulating emission of smoke and other pollution of the air within the city of St. Paul was approved in 1949 (58). The ordinance contains definitions, provides for the appointment of an advisory board, places responsibility with the Commissioner of Public Utilities, and sets up standards for measuring smoke density. The ordinance prohibits smoke density greater than Ringelmann No. 2 with certain exceptions and dust concentrations in combustion gases in excess of 0.85 pounds per 1,000 pounds of gas adjusted to 12 per cent carbon dioxide. It limits process dust emissions to 0.85 pounds per 1,000 pounds of gas, prescribes the procedure for measurement, and requires that certain fuel burning equipment be provided with dust separating equipment. The ordinance prohibits emission of air contaminants which cause injury, detriment, nuisance, or annoyance or which endanger comfort, repose, health, or safety, or which cause injury or damage to property or business. Smoke indicators are required on solid or liquid fuel burning plants of certain size.

Control Activity

Minneapolis: The staff of the Air Pollution Control Division consists of one engineer, one half-time secretary, and one occasional helper. Other branches of city government supplement and assist the division. For example, the Fire Prevention Bureau aids by policing the fire hazard associated with open burning and incinerator practices. The Health Department has made its laboratory facilities available, gives technical help, and assists in policing operations. The division's engineer spends most of his time on complaint investigation and enforcement activities (Table XXVI).

St. Paul: Many staff members of the Department of Public Utilities work part time on air pollution control. The overall effort on air pollution control probably totals two full-time investigators and one half-time secretary.

Table XXVI gives an estimate of the distribution of staff activity. Other city departments (fire, building, and health) supplement the utilities department in air pollution work.

TABLE XXVI
Distribution of Air Pollution Activity in Per Cent - 1959

Activity	Minneapolis (26)	St. Paul (27)
Complaint investigation	30	50
Enforcement activities	30	25
Air sampling and research	15	10
Administration (fees)	10	5
Public relations	5	5
Other	10	5

Sampling activities in the Twin Cities are limited due to lack of personnel, equipment, and specific appropriations for air sampling, but the departments have conducted dustfall, soiling, and suspended particulate sampling on a small scale. Laboratory assistance has been given and equipment loaned by other agencies.

Problem Trends

Minneapolis: The Air Pollution Control Division received 268 complaints in 1957, 310 in 1958, and 509 in 1959. In November 1959, 88 complaints were investigated.

During 1958-1959 one-half of all registered complaints concerned smoke (Table XXVII). Refuse incinerators (commercial, public, and private) accounted for the bulk of the smoke complaints, but smoke from coal and oil fired units were frequently the basis for complaints. Dust emissions from grain handling and processing, asphaltic paving material mixing and aggregate drying operations, and fly ash from incomplete combustion of fuel were other sources of complaints, as were bothersome odors stemming primarily from food and food products industries, asphaltic paving material plants, incinerators, and dumps. Violations of the city ordinance were most frequently due to improper coal combustion.

TABLE XXVII
Distribution of Complaints in Per Cent - 1959

Pollutant	Minneapolis (26)	St. Paul (27)
Odor	25	7
Dust	20	72
Smoke	49	16
Miscellaneous	6	5

St. Paul: The majority of complaints received by the Department of Public Utilities concerned dust (Table XXVII). While smoke sources have been reduced by the control program and by the decreasing number of coal fired units, dust sources have received more and more attention by the public. Household incinerators are a major problem in the city. Industrial activity and improperly operated or maintained heating plants add to the pollution. The department is working with other city offices to reduce visible emissions from municipally owned trucks. In addition, private trucking companies occasionally are notified of excessive visible emissions.

Interjurisdictional Problems: Complaints registered with the Public Utilities Department of St. Paul show that pollution sources outside the city limits are responsible for an increasing number of St. Paul's problems. In 1951, after the new air pollution ordinance was adopted, over half of the complaints received were related to problems outside the city, but these dropped off rapidly in succeeding years. Over the 1950-1960 period interjurisdictional complaints have amounted to about 10 per cent of the total number received. Major problems involve odors from the oil refinery, ammonia plant, and acid plant complex at Pine Bend, the oil refinery in St. Paul Park, and the packing houses and stockyards in South St. Paul. Others arise from burning dumps or from refuse burning by building contractors.

Minneapolis reports that 15 to 20 complaints per year concern interjurisdictional problems. Burning dumps, scrap auto burning, asphaltic paving material plants, fertilizer plants, oil extraction plants, and foundries are typical of the sources creating interjurisdictional problems.

Suburban communities also report complaints concerning sources of pollution in adjacent areas. A number of these communities have sought the advice of the air pollution programs in the central cities on means for controlling problems in their own and adjacent communities.

Protection of Air Resources

The most desirable program probably would be one which would serve the entire metropolitan area. Such a program would provide the lowest per capita cost per square mile of coverage. This type of operation would provide the most efficient and economical use of specialized costly equipment, laboratory facilities, and trained experienced personnel. Control of air pollution sources could be realized regardless of location in the area. Such an air pollution control district could conceivably come about through voluntary arrangement of interested jurisdictions, but statutory provisions for cooperative services involving two or more jurisdictions are generally more satisfactory.

Legislation: Existing legislation is inadequate, especially as it pertains to fourth-class cities, villages, townships, and counties. Uncertainty as to the authority of political jurisdictions to form an air pollution control district, or to expend money for such an intergovernmentally sponsored program, and the question of delegation of authority has deterred effective action on interjurisdictional problems.

The five-county area contains in excess of 250 local governmental subdivisions, including 51 townships, 104 municipalities, and 90 school districts.

In recent years there has been a marked growth in the number of municipalities in the area; 45 new municipalities have been created since World War II (Figure 24).

Special service districts such as the Minneapolis-St. Paul Airports Commission, the Minneapolis-St. Paul Sanitary District, and the Twin Cities Metropolitan Planning Commission operate pursuant to specific state statutes. Others such as the Metropolitan Mosquito Control District operate under the Joint Powers Act, which permits two or more units of government to perform jointly any function they are empowered to perform singly. Whether this act could be used as a basis for metropolitan air pollution control has not been legally determined.

Administration: The 1957 tax levy for local government in the five-county area was estimated to produce $160 million (54). Public expenditures for air pollution control in the Twin Cities area are estimated at less than $20,000 per year. Based on a population of one and one-half million people, air pollution expenditure is a little over one penny per capita per year; for the Minneapolis and St. Paul population, the expenditure is around two cents per capita.

A national survey in 1956 showed that, of 46 cities with an air pollution control program, costs ranged from two cents to 53 cents per capita and averaged 11 cents (60). The professional and technical employees necessary to operate these programs averaged one and one-half persons per 100,000 population served.

Planning: The Twin Cities Metropolitan Planning Commission has summarized the forward thinking of leaders in the planning field on air pollution (61). "Owing to other important considerations, potential air pollution sources cannot always be located where they will be least offensive. Control measures will be needed to clean up the existing air pollution in the area and to prevent additional pollution. While the enforcement of air pollution control ordinances by individual communities would aid in this effort, the problem requires area-wide action for a complete solution."

Development of an active area-wide advisory or planning committee on air pollution control, with members representing the various professional, civic, and political agencies concerned with the problem, is one means of promoting air pollution programs beneficial to the metropolitan area as a whole.

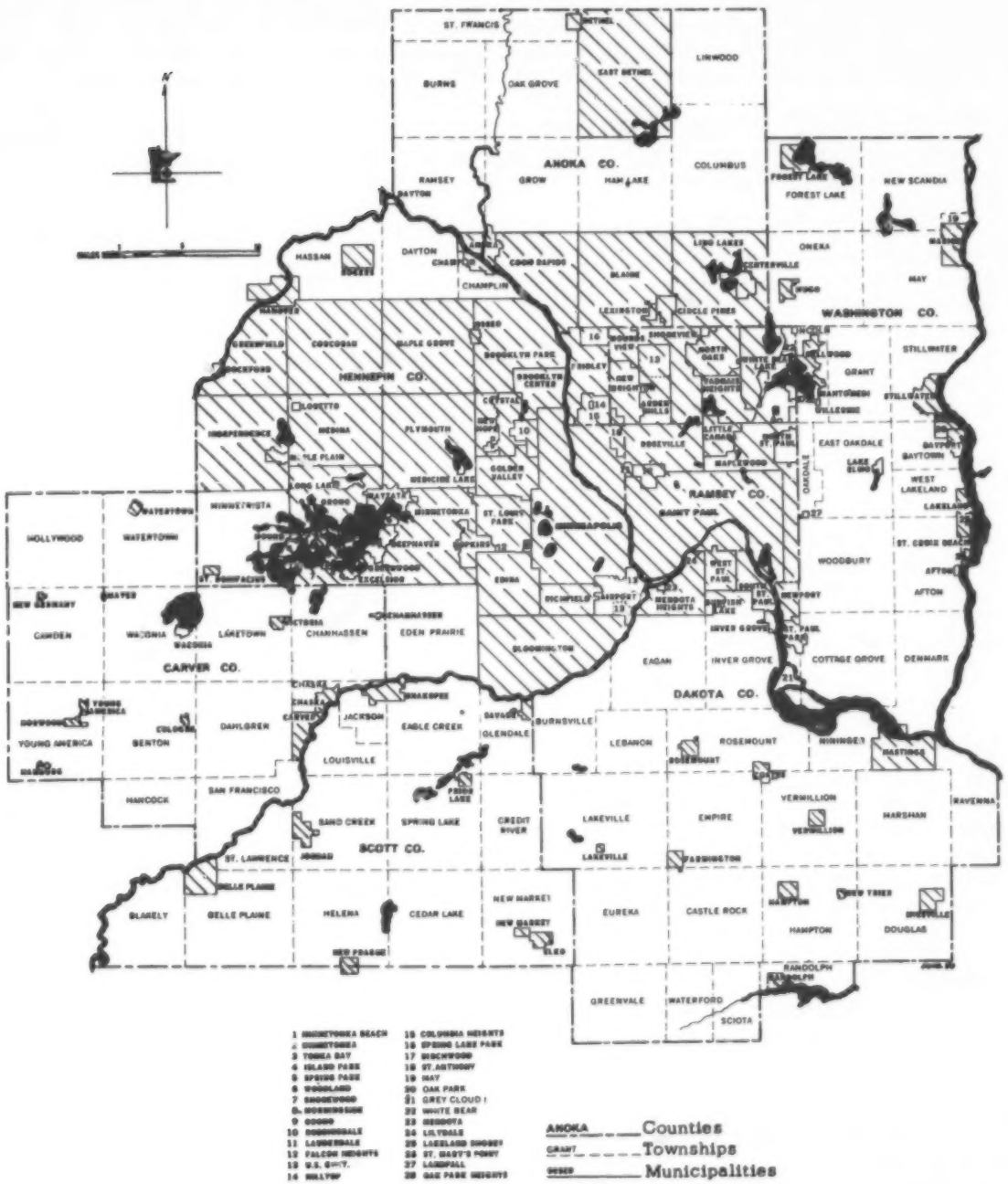
DULUTH

Duluth, located in St. Louis county on the western tip of Lake Superior, lies on and at the base of a range of hills that rises abruptly to as much as 800 feet above the level of Lake Superior. Duluth extends along the north bank of the Saint Louis River and Lake Superior.

Prevailing winds are from the east (off the lake) from April to August and from the west and northwest from September through March. Heavy fog, occasionally lasting into the second day, is reported on an average of 27 days per year. Weather and terrain may combine to limit the ability of the atmosphere to adequately disperse pollution at times.

Figure 24

TOWNSHIPS AND INCORPORATED AREAS - 1959
(Twin Cities Metropolitan Planning Commission) (54)



Population

Duluth grew rapidly up to 1920, when it had a population of 99,000. The 1960 census figures show a growth to only 106,884 people.

Duluth has a sister city occupying the flats across the bay, Superior, Wisconsin. The main parts of the Twin Ports are separated by about one mile of water. Superior has a 1960 population of 33,000 people (slightly less than in 1950). The standard metropolitan area, which includes all of St. Louis and Douglas (Wisconsin) counties, contains approximately 273,000 people (50).

From an air pollution potential standpoint, Cloquet, with its forest product industries, and Proctor, with its ore train marshalling yards, should be considered in the metropolitan complex.

Future growth of Duluth and surrounding areas may be favorably influenced by certain resources not yet exploited. Factors which affect the economy of northeastern Minnesota are reflected in the economy of Duluth (9). Explorations in 1948 showed nickel and copper deposits in the three northeastern counties of the state. Work is presently being carried out to determine the feasibility of developing these deposits. Certain manganese ores are being processed on the Cuyuna Range to the west. Minnesota's peat reserves of seven billion tons probably exceed the total reserves of the rest of the nation, but only limited use is being made of this material. Research may indicate some future possibilities for peat.

With the opening of the St. Lawrence Seaway, ocean vessels are now serving Duluth. The opening may result in the development of new industries and expand the population in the area, both of which would add to the air pollution load. The manufacturing industry, especially the primary metals industry, may expand as low cost power is made available to the area and low cost transportation to Europe is realized.

Sources of Pollution

Major sources of air pollution which have created complaints in recent years are industrial plants, dry cleaning and laundry establishments, heating plants of private and commercial buildings, motor vehicles, railroads, lake boats, and incinerators. Six complaints per month are received at the health department regarding backyard burning alone.

Industrial sources of process emissions include two steel plants, several foundries, a cement plant, and grain elevators. Boat loading operations on Lake Superior result in emissions of iron ore and grain dusts. The increased volume of shipping may increase the emissions from loading and unloading operations. The kraft paper mill in Cloquet and the oil refinery in Wrenshall have not been major causes of complaint in Duluth.

It was reported that pollutants in certain cases were in sufficient concentration to have caused measurable discomfort or inconvenience to residents and damage to property and vegetation. The complaints frequently come from private individuals, but community clubs have initiated some.

Fuel usage in the city shows industry using large amounts of coal. Domestic units use primarily fuel oil. Natural gas, which reached Duluth in December 1959, is expected to change the present fuel use pattern.

Ordinance

A smoke ordinance was adopted October 1931 by the city of Duluth (62). This ordinance declares that, with certain exceptions, the emission of dense smoke is a public nuisance, prohibits same, and holds owners and operators responsible for dense smoke from railroad locomotives, steamboats, tugs, derricks, pile drivers, buildings, and portable boilers. It prohibits open burning of garbage and refuse, creates a smoke inspection department, specifies duties and obligations of the smoke inspector, establishes a smoke abatement commission and delineates its powers, provides for installation and alteration permits for heating and power plants, and establishes fees.

Activity

For approximately the past 15 years, no funds have been appropriated for the smoke inspection department, thus nullifying the intent of the ordinance.

In view of the nature and frequency of complaints received, the potential expansion of industrial activity in the area, and the likely possibility of an interstate problem occurring, the local political jurisdiction should initiate control activities to reduce present air pollutants and maintain a satisfactory air environment.

APPENDIX

MINNESOTA DEPARTMENT OF HEALTH
Division of Environmental Sanitation

AIR POLLUTION APPRAISAL QUESTIONNAIRE
October 1, 1959

	YES	NO
1. Are there <u>any</u> operations (municipal, domestic, industrial) in or near your area of jurisdiction that emit noticeable amounts of smoke, fumes, dust, or odor to the atmosphere?	( )	( )
2. In your opinion, are these pollutants in sufficient concentration to cause:		
a. Measurable discomfort or inconvenience to residents?	( )	( )
b. Damage to property? (autos, paint, clothing, buildings, etc.)	( )	( )
c. Damage to vegetation? (lawns, crops, flowers, etc.)	( )	( )
d. Injury to animal life?	( )	( )
3. Have you received complaints of air pollution in the last 2 years?	( )	( )
4. Do any of the problems result from seasonal activities?	( )	( )
5. Are there any local ordinances or regulations for the control of smoke, fumes, dust, and odor?	( )	( )
6. Do you know of any activities planned for the future in your area which might contribute to air pollution?	( )	( )
7. Have any steps been taken to control sources of air pollution in your area?	( )	( )
8. Are there any other organizations (official or unofficial) in your community who might furnish additional information regarding air pollution problems?	( )	( )

9. Use this space and other side to explain or enlarge upon any "yes" answers.

Signed_____

Title _____

City _____

County_____

Return in self-addressed envelope to:

State of Minnesota
Department of Health
University Campus
Minneapolis 14, Minnesota

MINNESOTA DEPARTMENT OF HEALTH
Division of Environmental Sanitation

AIR POLLUTION APPRAISAL
Agricultural Questionnaire
October 1959

	YES	NO
1. Are there <u>any</u> operations (municipal, domestic, industrial, agricultural) in your area of jurisdiction that emit noticeable amounts of smoke, fumes, gases, dust, or odor to the atmosphere?	( )	( )
2. In your opinion, are these pollutants present in sufficient concentration to cause damage or injury to:		
a. Vegetation? (including interference with natural growth)	( )	( )
b. Animal life?	( )	( )
3. Have you received complaints of air pollution damage to plant or animal life in the last two years?	( )	( )
4. Please describe briefly any air pollution problems in your jurisdiction. Give sources, nature of damage, and severity of the problem.		
5. Have any steps been taken to control sources of air pollution in your area? Describe.	( )	( )

Return in self-addressed envelope to:

State of Minnesota
Department of Health
University Campus
Minneapolis 14, Minnesota

Signed_____

Title _____

City _____

County_____

MINNESOTA DEPARTMENT OF HEALTH
Division of Environmental Sanitation

MUNICIPAL REFUSE DISPOSAL QUESTIONNAIRE

Name of Community	Refuse Collection				Refuse Disposal								Remarks (Use other side if necessary)
	Garbage		Rubbish		Hog Feeding		Incineration		Dump Operation				Backyard Burning		
	Yes	No	Yes	No	Yes	No	Yes	No	Land-fill	Open Dump	Location	Control at Dump	Burning at Dump	Yes No	

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